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REPORT #
RRTAC 91-1

Reclamation Research

Annual Report - 1990

Heritage Fund

Alberta

LAND CONSERVATION AND
RECLAMATION COUNCIL
Reclamation Research
Technical Advisory Committee

DISCLAIMER

This report is intended to provide government, industry and the public with a summary of the research that is being carried out by the provincial government's Reclamation Research Technical Advisory Committee. Additional information on the Reclamation Research Program and additional copies of this report may be obtained by contacting:

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RECLAMATION RESEARCH

ANNUAL REPORT - 1990

prepared by

The Reclamation Research Technical Advisory Committee

for the

ALBERTA LAND CONSERVATION AND RECLAMATION COUNCIL

1991

ACKNOWLEDGEMENTS

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Photographs for the report come from the consultants and from the files of Mr. C. Powter.

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January 28, 1991

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1. INTRODUCTION

Regulating surface disturbances in Alberta is the responsibility of the Land Conservation and Reclamation Council. The Council executive consists of a chairman from the Department of Environment (Mr. John King, Director, Land Reclamation Division) and two deputy chairmen from the Department of Forestry, Lands and Wildlife (Mr. Roger Marvin, Director, Land Management and Development Branch and Mr. Don Fregren, Director, Forest Land Use Branch). Among other functions, the Council oversees programs for reclamation of abandoned disturbances and reclamation research. The Reclamation Research Program was established in 1978 to identify the most efficient methods for achieving acceptable reclamation in Alberta. Funds for implementing both the operational and research programs are drawn from Alberta's Heritage Savings Trust Fund, Land Reclamation Program.

To assist with the development and administration of the research program, the Council appointed the Reclamation Research Technical Advisory Committee (RRTAC). The Committee consists of six members and a secretary:

Chris Powter (Chairman) - Alberta Environment, Land Reclamation Division

Sharon Guenette (Secretary) - Alberta Forestry, Lands and Wildlife, Forest Land Use Branch

Leon Marciak - Alberta Agriculture, Conservation and Development Branch

Reinhard Hermesh - Alberta Environmental Centre, Plant Sciences Division

David Lloyd - Alberta Forestry, Lands and Wildlife, Public Lands Division

Sam Takyi - Alberta Forestry, Lands and Wildlife, Alberta Forest Service

Stephen Moran - Alberta Research Council, Environmental Research and Engineering Division.

The following are ad-hoc members of RRTAC:

Hugh Wollis - Alberta Forestry, Lands and Wildlife, Fish and Wildlife Division

Hari Sahay - Alberta Energy, Scientific and Engineering Services and Research Division

RRTAC's mission is to coordinate and foster reclamation research in Alberta. To this end, the Committee updates priorities, reviews research proposals, and organizes workshops.

1.1 PROGRAMS

RRTAC conducts research in four major program areas, which correspond to Alberta's major industrial activities and biophysical regions: Plains Coal, where agricultural concerns are dominant; Mountains and Foothills Coal, where recreation, forestry, wildlife and watershed concerns are the focus; Oil Sands, where wildlife and forestry concerns exist; and, Oil and Gas, where agricultural and forestry concerns are examined.

While it is expected that research results will often have province-wide application, the division of the research among the four programs has proven helpful in identifying priorities and directions.

The objectives of the research projects are:

1. To develop methods that will make reclamation a more efficient and effective process;

2. To provide scientific data to enable sound decision making in the regulatory and operational reclamation stages; and,

3. To provide scientific data to evaluate the effectiveness of reclamation guidelines and criteria.

RRTAC research projects are trials for new technologies, and new proposals are reviewed and rated on their adherence to priorities, likelihood of success and competence of researchers. Throughout the review process, the key question is: "Would this information make reclamation in Alberta a more efficient process?"

1.2 MANAGEMENT AND FUNDING

Every effort is made to involve industry in management and funding of the research to ensure the projects address real field concerns. Cooperation with industry facilitates agreement on reclamation research priorities and early implementation of research results in operations and planning.

The following companies and agencies were involved with the design, management and review of RRTAC projects this year:

Agriculture Canada

Alberta Agriculture

Alberta Energy, Scientific and Engineering Services and Research Division

Alberta Energy Resources Conservation Board

Alberta Environment, Land Reclamation Division

Alberta Environment, Wastes and Chemicals Division

Alberta Environmental Centre, Environmental Technology Division

Alberta Environmental Centre, Plant Sciences Division

Alberta Forestry, Lands and Wildlife, Alberta Forest Service

Alberta Forestry, Lands and Wildlife, Fish and Wildlife Division

Alberta Forestry, Lands and Wildlife, Public Lands Division

Alberta Power Limited

Alberta Research Council, Environmental Research and Engineering Division

Bow Valley Industries Ltd.

Canadian Parks Service

Cardinal River Coals Ltd.

Crows Nest Resources Limited

ESSO Resources Canada Ltd.

Fording Coal Ltd.

Gregg River Resources Ltd.

Luscar Ltd.

Luscar Sterco (1977) Ltd.

Manalta Coal Ltd.

NOVA Corporation of Alberta

Obed Mountain Coal Company Limited

OSLO

Peace Pipe Line Ltd.

Shell Canada Resources Limited

Smoky River Coal Ltd.

Suncor Inc.

Syncrude Canada Limited

TransAlta Utilities Corporation

The following agencies and companies provided additional research funding for RRTAC projects this year:

Alberta Environmental Centre

Alberta Research Council

Canadian Parks Service

Canadian Petroleum Association

Independent Petroleum Association of Canada

Suncor Inc.

Syncrude Canada Limited

TransAlta Utilities Corporation

In addition to the above, Alberta's oil and gas industry provided $585 000 funding for an extensive analysis of drilling wastes. The total level of funding provided by these outside sources for 1990 was $1 028 210 which allowed RRTAC to undertake a significantly larger research program for the province than would otherwise have been possible.

1.3 SIGNIFICANT EVENTS IN 1989

RRTAC initiated several projects during the year with a new set of funding partners - the Canadian Petroleum Association, the Independent Petroleum Association of Canada and the

oil and gas industry in general through the government/industry Drilling Waste Review Committee. We have also interacted with the government/industry Alberta Pipeline Environment Steering Committee to develop projects and assist in providing data for their decision making processes. We welcome the partnership with this important segment of the reclamation community.

The RRTAC Chairman presented papers on RRTAC goals and functions at several conferences, workshops and seminars this year. In addition, several papers arising from RRTAC funded projects were presented during the year by the consultants who performed the work. These efforts are an important method of communicating RRTAC activities to Albertans and others, and will be increased in the future.

1.4 REPORTS

Upon project completion, a final report is submitted. Some are published intact as RRTAC Reports and released to the public. Others are held, pending their inclusion in comprehensive RRTAC Reports. Since 1978, RRTAC has produced 70 reports and workshop proceedings on a wide variety of topics. The reports are available at a small cost from Publication Services, Queen's Printers, 11510 Kingsway Avenue, Edmonton, Alberta T5G 2Y5. Section 9 provides a listing of available reports.

RRTAC made a decision to switch to recycled stock for all of its reports, starting with RRTAC 89-3. This step was taken in recognition of the increasing volume of paper used by the program and the public's growing environmental awareness and desire for the government to lead the way in environmental protection.

1.5 CONTENTS OF THIS REPORT

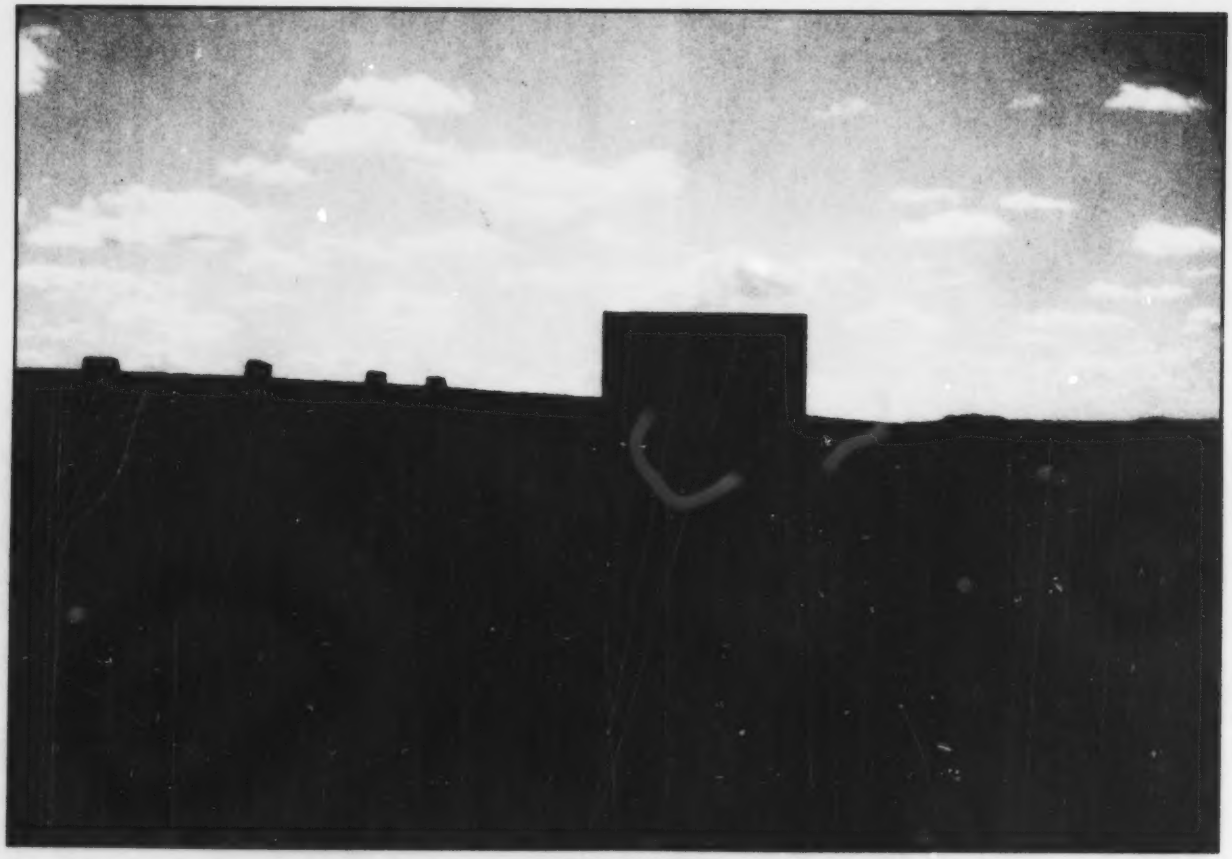
Following is a summary of the most recent research projects as of March 31, 1991. Budget details are given in Section 8. Information on previous projects is given in Section 7 and in previous annual reports. The 5-year research plan for RRTAC is shown in Figure 1.

Additional information on the Reclamation Research Program may be obtained by contacting:

Mr. Chris Powter, Chairman
Reclamation Research Technical Advisory Committee
3rd Floor, Oxbridge Place
9820 - 106 Street
EDMONTON, Alberta
T5K 2J6
Telephone: (403) 427-4147

PROGRAM	1989	1990	1991	1992	1993
PCRRP	Effects of Perched Ponds				
	Battle River Soil Reconstruction Project				
	Use of Spoil as Subsoil Material →				
		Technology Transfer →			
MFRRP	Salinity Screening of Native Grass Species				
	Reclamation of Disturbed Alpine Lands				
		Selection, Evaluation and Multiplication of Native Legumes			
			Topsoil Depth →		
OGRRP	Compaction on Oil & Gas Leases (Costs covered by AEC →)				
	Literature Review on Drilling Waste Burial				
	Update of Drilling Waste Disposal Manual				
	CPA Sump Chemistry Study →				
	Landfarming of Invert Drilling Wastes →				
		Soil Sterilants Issue Scoping			
		Three-Lift Soil Handling Workshop			
		Winter Soil Surveys			
		Sterilants Field Study →			
		Reclamation of Mixed Grass Prairie Disturbed by Pipeline Construction			
			Three-Lift Soil Handling Field Study		
			Technology Transfer of Drilling Wastes Information		
				Drilling Waste on Class 1-4	
OSRRP	An Analysis of Vegetation Data from Reclaimed Oil Sands Areas				
	Oil Sands Soil Reconstruction Project				
		Dewatering of Tailings Sludge →			
		Effective Capping Depths for Tailings Sand →			
GENERAL	Update of Plant Species Suitability Manual				
	Review of Erosion Control Materials & Methods				
	Effects of Storage on Topsoil Quality				
	User Guide to Pit & Quarry Reclamation in Alberta				
		Physical Properties of Reclaimed Land →			
		Land Capability Classification			
			Reclamation of Cutover Peatlands		
	Publications →				

Figure 1. Five Year Research Plan



Reclamation success at the Paintearth Mine near Forestburg.

Plains Coal Reclamation Research Program

Members: Chris Powter (Chairman) - Alberta Environment; Lilli Chevrier (Secretary) - Alberta Environment; Ken Crane - Luscar Ltd.; John Dormaar - Agriculture Canada; Katherine Gizikoff - Manalta Coal Ltd.; John Hastie - TransAlta Utilities; Ken Johnson - Edmonton Power; Richard Johnson - Alberta Environmental Centre; Jivan Kayande - Alberta Power; Chong Ko - Alberta Environment; Dermot Lane - Fording Coal Ltd.; Leon Marciak - Alberta Agriculture; Wayne Tedder - Alberta Forestry, Lands & Wildlife.

2. PLAINS COAL RECLAMATION RESEARCH PROGRAM

The Plains Coal Reclamation Research Program (PCRRP) has been designed by the provincial government and members of the coal industry to answer questions relating to groundwater and soil reconstruction in plains coal mining zones. Efforts are focused in two main areas:

1. Soil reconstruction will indicate how to rebuild agricultural soils after mining; and,
2. Hydrology will describe what happens to groundwater during mining and after reclamation, and how to rebuild the landscape to maximize its agricultural potential.

The Program has been jointly managed by the provincial government and coal industry personnel.

2.1 RECLAMATION OBJECTIVES

To return cropland to pre-mining levels of capability which includes both agricultural and hydrologic capabilities.

2.2 THE PROBLEM

Coal is surface mined in two major zones in Alberta: the Ardley Zone running southeast from Mayerthorpe to Red Deer, and the Horseshoe Canyon Zone which runs parallel and to the east from Barrhead through Camrose to Drumheller (Figure 2). The Ardley Zone is surface mined near Lake Wabamun to provide coal to the Wabamun, Sundance, Keephills, and Genesee power plants. The Horseshoe Canyon Zone is mined on either side of the Battle River between Forestburg and Halkirk. These mines supply the Battle River Generating Station. Another power plant and mine have been developed to the south of Sheerness.

Plains coal seams are usually overlain by bedrock which contains a high proportion of swelling clays. When exposed to the elements, the bedrock shales and sandstones break down into a material that is sticky when wet and very hard when dry. This severely hinders plant growth and agricultural operations. Above the bedrock lie glacial deposits which are usually free of the most adverse properties of the bedrock though they lack the plant nutrients and organic matter which are characteristic of the overlying topsoil.

Rebuilding a soil profile is one of the major problems in cropland reclamation in Alberta. A soil must be built on levelled overburden which will have similar capability to the original soil. Existing evidence indicates that placing topsoil and a buffering material over the spoil is the most efficient method for achieving this goal (Figure 3). When topsoils or subsoils are in short supply, other materials may be useful in constructing a suitable rootzone medium. In addition to soil reconstruction, certain agricultural practices like green manuring and legume cropping may help rebuild the soil.

In many plains areas, the coal seams are the major source of domestic water. What will happen when the coal is removed and overburden fills the mined-out pit? The behaviour of the post-mining groundwater system will affect water users and could influence future agricultural potential. However, prior to the Plains Coal Reclamation Research Program, little was known about the effects of surface mining on groundwater in Alberta.

2.3 RESEARCH FOCUS

Work in 1990 focused on the use of alternate materials for soil reconstruction, and on initiating a program to transfer the technology developed during the past 12 years to government and industry.

2.4 SOIL RECONSTRUCTION

Use of Spoil as Subsoil Material - D. Chanasyk, University of Alberta, Soil Science Department

When crop lands are reclaimed, the minespoil is returned to the mine pit, then a layer of subsoil is replaced to a depth that will allow return of capability, and covered with the available topsoil. The replaced subsoils usually come from the first metre to metre-and-a-half of material under the topsoil. However, there are

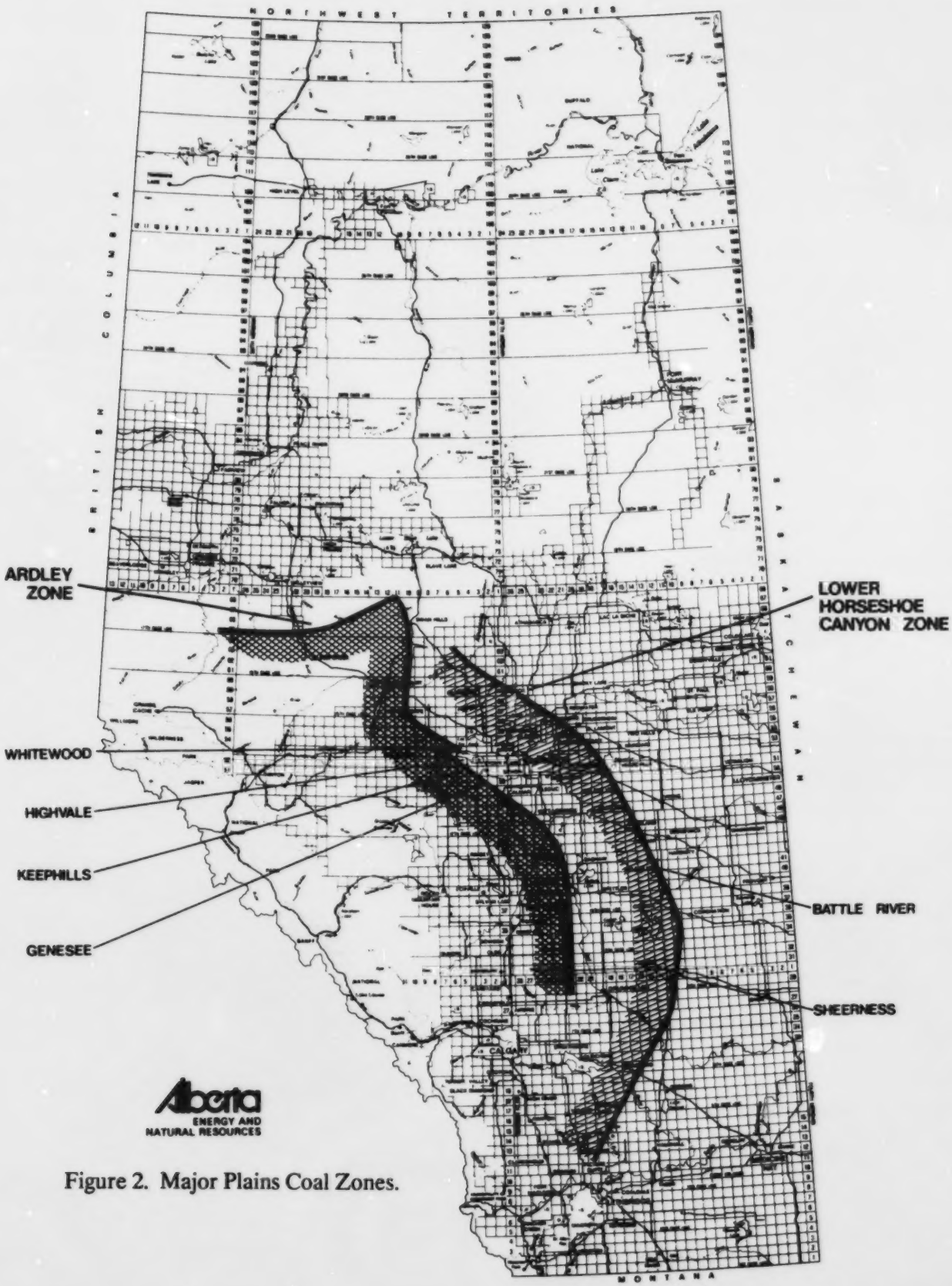


Figure 2. Major Plains Coal Zones.

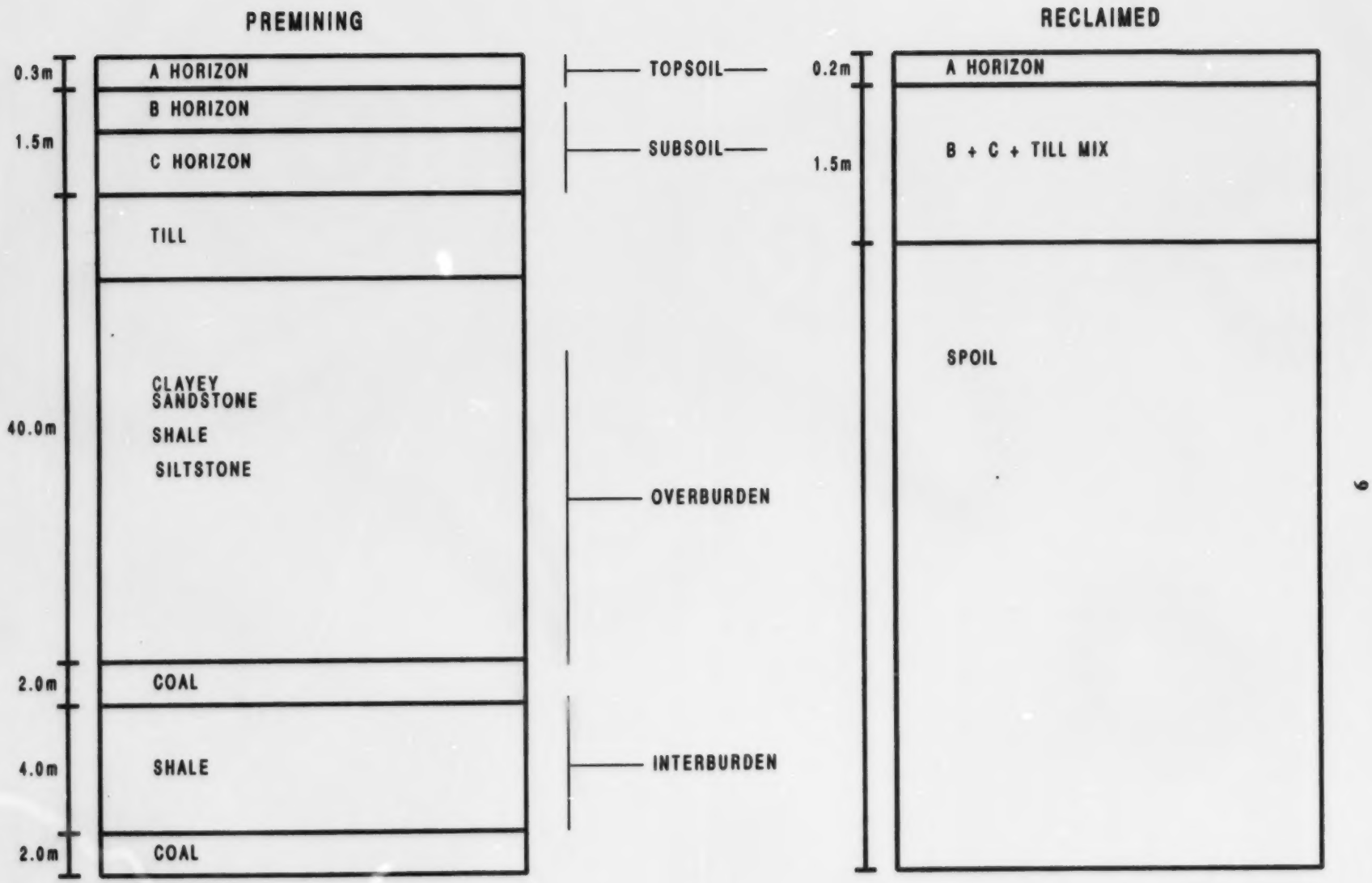
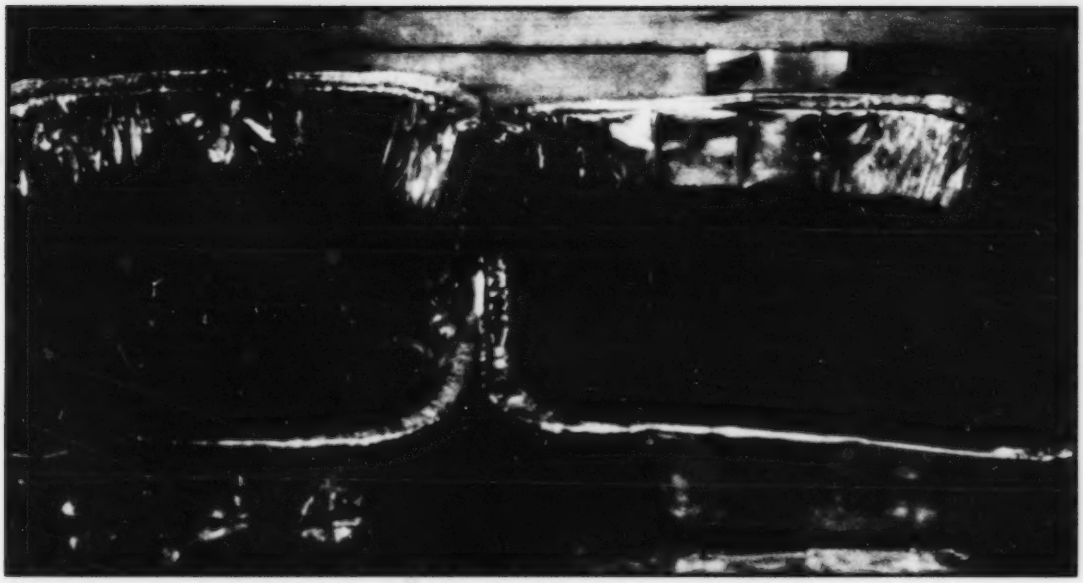


Figure 3. Generalized Soil Profiles.



The grey spoil (left) is being compared to the brown spoil to determine the suitability of the grey material for use as subsoil.

some cases where the material below this (up to several metres in depth) may be suitable for use as subsoil according to some commonly used criteria (texture, salt content, pH). Such is the case at the Highvale Mine west of Edmonton.

The objectives of this project are:

1. To determine if sandy spoil materials at the Highvale Mine are suitable for use as subsoil material, and

2. To determine the need for modification of the Alberta Soil Quality Criteria for subsoil.

The study reviewed the existing database on chemical and physical characteristics of the materials and evaluated the moisture holding capabilities of the subsoils in the laboratory using lysimeters. The brown subsoil material is rated as "good" (ECdS/m; SAR; Saturation % 30 to 60). The grey subsoil is rated as suitable although its SAR is 13 (soils with SAR between 12 and 20 are considered suitable if texture is sandy loam or coarser - i.e., clay content is less than 20% - and the Saturation % is less than 100).

As a result of these analyses, a detailed field study to further evaluate these materials was put in place. Large areas of shallow (brown) spoil and deep (grey) spoil, and a mixture of the two spoil materials were established and topsoiled. The areas were seeded to a cereal cover crop and underseeded to forage. Soil moisture and crop growth were evaluated this year.

Status: The project is ongoing and is being co-funded by TransAlta Utilities Corporation.

2.5 WATER RELATIONS

Plains Hydrology and Reclamation Project - S.R. Moran, Alberta Research Council

This study examined the impacts of surface mining on the regional groundwater, geology and soils. The main objectives included the identification of:

1. changes in groundwater quality and quantity after mining;
2. sources and release rates of salts to groundwater;
3. changes in distribution of groundwater after mining (Will the watertable drop or will it re-establish at pre-mining levels?);
4. changes in soil chemistry as a result of groundwater return; and,
5. surface stability after mining (subsidence, piping).

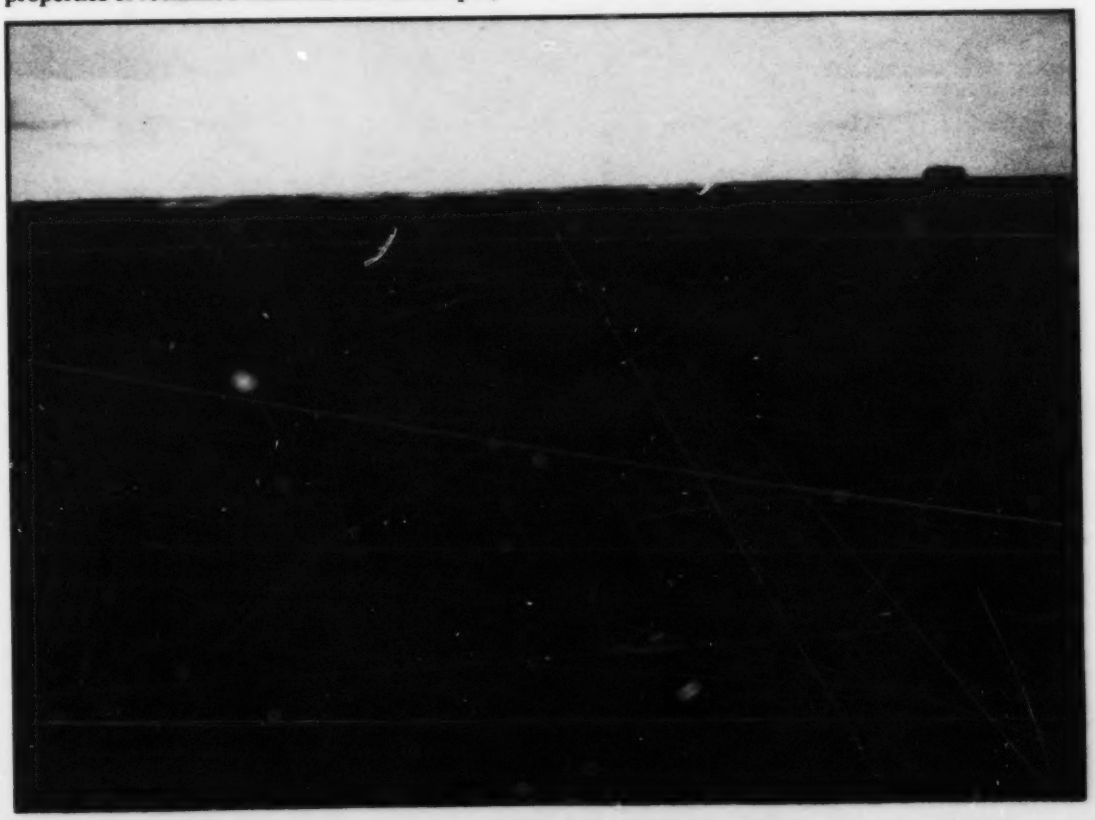
Critical groundwater and geologic parameters were identified which allow us to predict the "reclaimability" of a site prior to mining. This project began in 1979 and was conducted in the Battle River and Highvale mining areas.

The most significant achievement this year was the release of the summary report for the project. The report outlines: the project goals and objectives; the basis for extrapolation of results to other sites; characterization of the two study areas; properties of reclaimed materials and landscapes; impacts of mining and reclamation on post-mining land use; and, implications for reclamation practice and regulation.

Status: The Alberta Research Council continues to conduct work under its own funding. Approximately 25 research reports are expected to be generated from this research project. Several reports have already been released: RRTAC 86-2, 86-3, 86-4, 86-5, 86-7, 87-9, 87-10, 87-11, 87-12, 87-13, 88-2, 88-4, 88-9, 88-12, 89-3, 89-7, 90-4, 90-8, and 90-10.

Effects of Perched Ponds on Groundwater and Salinity - S. Moran, Alberta Research Council

The objective of this study was to determine the potential effects of perched ponds in reclaimed plains coal mine sites on agricultural capability. The study concluded that the ponds are created as a result of the formation of closed drainage basins coupled with the formation of a low permeability base. The low permeability may be the result of compaction during placement and regrading of the spoil and subsoil.



Ponds in the reclaimed landscape may lead to salinization of the soil around the pond margin and create problems for farm equipment movement.

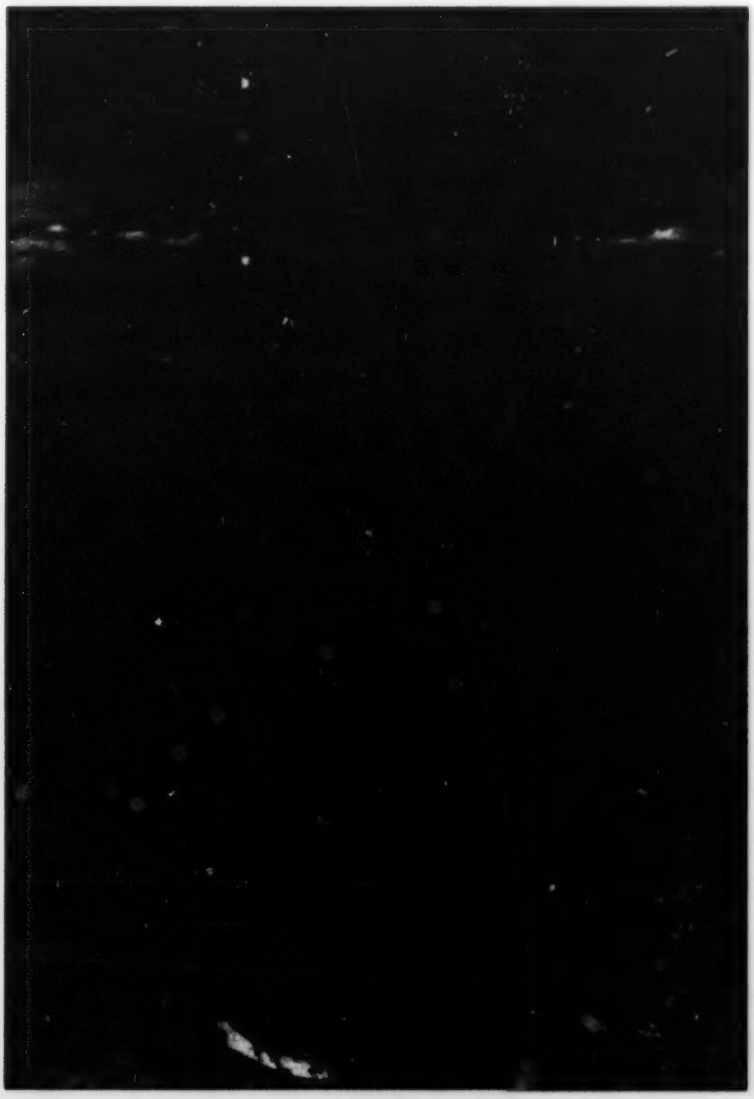
Ponds may affect capability in three ways: (1) they may reduce the amount of farmable land and disturb field patterns; (2) they may result in progressive development of saline and potentially sodic soils in the area adjacent to the pond; and, (3) they result in accelerated groundwater recharge, at least in their early stages. To put these concerns in perspective, however, it is important to note that ponds in reclaimed settings appear to cover less than half the area that ponds in undisturbed landscapes do.

Status: The project is completed and a final report has been published: RRTAC 90-4.

Water Balance in Sodic Spoil - R. Johnson, Alberta Environmental Centre

Work conducted by the Alberta Research Council has shown that depth of the watertable in a saline sodic soil system can have a great effect on the quality of the rooting zone soil.

This study was initiated in 1986 to determine the effects of crop type, depth to groundwater and microclimate on salinity and water movement in reclaimed soils. Large lysimeters (75 cm wide x 100 cm deep) were developed at



Two lysimeters are shown - one planted to forage and one to grain - with the manometers used to read water level in the soil.

the Alberta Environmental Centre and were planted to annual grain (wheat or barley), forage (alfalfa), or left fallow. One half of the lysimeters have a watertable maintained at 95 cm, the others are free draining.

The data collected over the life of the study will allow development of a model that can predict soil moisture content and movement over large areas with few data inputs. This will allow land managers to predict optimum locations for crops on a reclaimed landscape and to predict the effects of those crops on soil water balance.

Status: The project is ongoing and is being funded by the Alberta Environmental Centre. More information is available in AEC annual reports.

2.6 TECHNOLOGY TRANSFER

Technology Transfer - D. Cheel, Alberta Research Council

The knowledge produced by the Plains Coal Reclamation Research Program needs to be communicated to the individuals and agencies concerned with resource development and land reclamation in order to derive full benefit from the work. Although the research results have been published, this alone does not adequately carry out the transfer of technology to those who can derive the most benefit from it. The project will develop a framework within which the knowledge and technology developed by PHRP and other RRTAC Plains Coal studies can be transfered to individuals in government, industry, and the general public.

For 1990, the work focused on the identification of concerns and questions raised by people actively involved in Plains region reclamation, from both regulatory and compliance viewpoints. Specifically, the consultant:

Transfer of research results (technology) to users can occur through many mechanisms.

1. Analyzed and reviewed the existing body of reclamation research needs data collected by Concord Scientific Corporation for RRTAC, as well as information ascertained from program subcommittees regarding future research needs. Reviewing research priorities from these sources will allow for identification of knowledge gaps that do not require further research but are technology transfer needs.

2. Interviewed key people, representative of the reclamation community. The results of the first activity were used as a basis for the questions asked in the intervies. The interviews were used to: (1) confirm the knowledge gaps identified above; (2) identify other concerns regarding reclamation research and the transferability of research results to operational considerations not identified above, and (3) identify a preferred method for transfer of the technology (i.e., workshops, short courses, field trips, others).

3. Summarized results of information gathering activities. Information collected through analysis of the Concord data and interviews was summarized to identify trends or similarities.

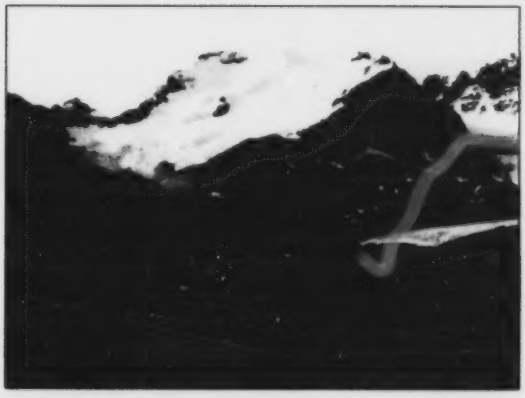
4. Using the results from the above work, prepared a preliminary workplan for the development of a program to address the concerns and questions identified.

Status: The work is ongoing.

It is also important to develop technology transfer mechanisms for the public.

Neutron probes are used to determine soil moisture status in research plots at Battle River.

Mountains and Foothills Reclamation Research Program



Members: Chris Powter (Chairman) - Alberta Environment; Lilli Chevrier (Secretary) - Alberta Environment; Marcellus Adamkewicz - OBED Mountain Coal; Vernon Betts - Smoky River Coal Ltd.; Jeff Bondy - Forestry, Lands & Wildlife; Curtis Brinker - Luscar Sterco; Rick Ferster - Luscar Ltd.; Reinhard Hermesh - Alberta Environmental Centre; Jim Lant - Crows Nests Resources; Bob Logan - Cardinal River Coal; Bernd Martens - Manalta Coal Ltd.; Tom Sneddon - Alberta Energy; Sam Takyi - Forestry, Lands & Wildlife; R. Zroback - Gregg River Resources Ltd.

3. MOUNTAINS AND FOOTHILLS RECLAMATION RESEARCH PROGRAM

In 1984, The Coal Association of Canada and RRTAC agreed to jointly fund and manage the Mountains and Foothills Reclamation Research Program (MFRRP). Over a period of five years the program addressed a number of issues that were applicable to mines throughout the region. Upon completion of those efforts, MFRRP agreed that future projects were likely to be of use to a much smaller group of mines (i.e., be site specific). Therefore, it was agreed that the program committee would continue to function in a review capacity, but that industry funding for future projects would likely come from individual mines, rather than from the Association.

3.1 RECLAMATION OBJECTIVES

1. Control of erosion on a variety of disturbances including coal mines, mineral exploration sites, and coal ash pits;
2. Return of forested lands to previous levels of capability; and,
3. Return of wildlife range to previous levels of capability.

3.2 THE PROBLEM

Reclamationists in the mountains and foothills face a wide variety of conditions. While some foothill sites are characterized by subdued terrain and moderate climate, other sites, particularly in the mountains, present steep slopes, rocky spoil and a short growing season. On these problem sites, summer droughts, chinook winds, erodible slopes and nutrient-poor soils are common.

On lower elevation foothill sites, reclamation is expected to yield forests with commercial potential while on the higher elevation mountain sites erosion control, and development of wildlife habitat and recreation potential are the reclamation objectives.

Reclaimed land in the mountains and foothills will not be as intensively managed as reclaimed agricultural lands would be. Also, topsoil and subsoil layers tend to be thin and difficult to handle selectively. Nonetheless, they are a valuable source of plant nutrients. So while some mixing of horizons is inevitable, how much is acceptable? How thick should the replaced soil layer be? Should the scarce topsoil be replaced evenly over the whole site, or in "islands" to provide a better growing medium in certain, designated areas? Other sites simply have no salvageable topsoil, and reclamation must prepare the site so that a plant-soil system will develop which will perform its land use expectations without indefinite fertilization.

3.3 RESEARCH FOCUS

There are four important aspects to reclamation in the mountains and foothills region:

1. The creation of stable reclaimable landscapes. This includes dump design (optimal slope, angles and lengths, terracing) and pit backfilling.
2. Preservation of watershed integrity and water quality. Water flow and sediment control from reclaimed slopes are of prime interest.
3. Reconstruction of a suitable growing medium for each land use. The goal is to make the best use of limited materials to improve the rootzone over rocky, nutrient poor spoil.
4. Selection of suitable vegetation for each land use and proper planting to ensure survival and growth. The goal is creation of a self-sustaining cover that does not require long-term maintenance.

Work in 1990 focused on the selection of suitable plant species for the region.

3.4 REVEGETATION

Selection of Native Grasses for Reclamation - R. Hermesh and B. Darroch, Alberta Environmental Centre

Many alpine and subalpine sites are difficult to reclaim simply because commercially available grasses and legumes either cannot survive or cannot reproduce in the short growing season. Where a long-term, maintenance free vegetation is the desired reclamation goal, both of these characteristics are crucial to success.

The Vegetation Branch of the Alberta Environmental Centre has undertaken a breeding project with the objective of selecting, testing, developing, and registering lines of native alpine grasses for use in reclamation, erosion control, and range improvement in the alpine and subalpine regions of Alberta.

Five native grass species were chosen for the breeding project: alpine bluegrass (*Poa alpina*), slender wheatgrass (*Agropyron trachycaulum*, including awnless [var. *trachycaulum*] and bearded [var. *unilaterale*] types), broadglumed wheatgrass (*A. violacuem*), spike trisetum (*Trisetum spicatum*), and sheep fescue (*Festuca saximontana*). These grasses are known to invade disturbances in sub-alpine and alpine areas. In 1984 and 1985, plants of each species were collected from 330 sites along the eastern slopes of the Rocky Mountains. Collected plants were transplanted to field nurseries at Vegreville. Initial selections were made from these nurseries, with final selections based on performance of the progeny of selected plants. Selections were made both on the basis of commercial potential and fitness for reclamation. Selections of wheatgrass and alpine bluegrass were tested at Vegreville, Columbia Icefields, Sunshine Village and Mountain Park in 1987 to 1989. Further selections were based on the performance of lines in these trials. In 1990, multi-location trails to test these selections (the final

Although they are small, native species in the mountains are very important for the success of high elevation reclamation. One of the lines of native grasses being tested in the Columbia Icefields is shown above.

step prior to registration of the best lines) were seeded at Vegreville, Beaverlodge, Columbia Icefields and Mountain Park. Spike trisetum and sheep fescue lines are also being evaluated but the selection and testing of these species was delayed by problems with seed production.

In addition to the plant breeding research, research has been conducted to study the agronomy and ecology of the target grass species. Seeding methods, date of seeding, and fertilizer requirements have all been studied. Research is being conducted on the requirements for floral induction in alpine bluegrass, the tolerance of the grasses to herbicides, and the resistance to slender wheatgrass to head smut. Management practices for establishment and maintenance of native grasses on disturbed areas are also being studied.

Status: The project is ongoing and is being funded by the Alberta Environmental Centre. More information is available in AEC annual reports.

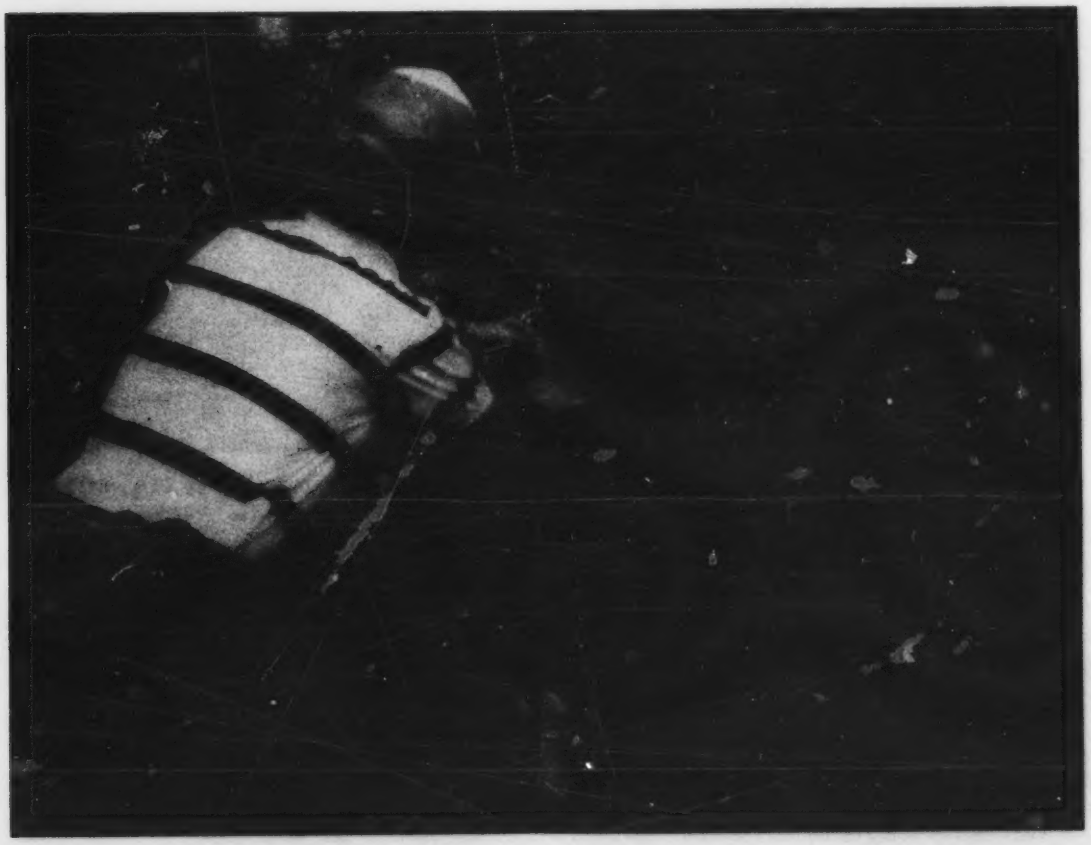
Salinity Screening of Native Grass Species - A. Smreciu

The objective of the work was to determine salinity tolerance of various lines of native wheatgrasses and alpine bluegrasses selected in the above project.

The work involved:

1. Screening approximately 1000 lines of alpine bluegrass for salinity tolerance and selecting tolerant lines.
2. Reconfirming the salinity tolerance of selected lines by repeating the screening tests.
3. Propagating the selected lines and repeating the tests on the progeny to see if tolerance is an inherited character.

Eleven of the slender wheatgrass lines and 72 of the alpine bluegrass lines had a higher percentage emergence than the control species



Native legume materials were collected as seed from harsh sites in the foothills and mountains. Native grasses, on the other hand, were collected as whole plants.

in saline solutions. The majority of the tolerant lines came from Crowsnest Pass, Burgess Mountain, Lake O'Hara and Lake Louise.

Status: The project is completed and a final report has been published: RRTAC 90-2.

Selection, Evaluation and Multiplication of Native Legumes - A. Smreciu, Wild Rose Consulting Inc.

Native legumes are adapted to a wide range of biotic, edaphic, and climatic conditions and possess attributes (e.g., nitrogen fixation, deep root systems) considered desirable in a reclamation species for mountain and ffothill regions of Alberta. The objective of this project is to collect, multiply, evaluate and select native legume species for reclamation.

Thirteen species, representing four common genera (*Astragalus, Hedysarum, Lupinus, and Oxytropis*), were collected from 34 sites in the Waterton, Banff, and Jasper National Parks. Seeds were collected, cleaned, and stored. Samples of each collection were sterilized, scarified, and tested for germination. Seedlings are being produced in greenhouses and growth chambers, and a field nursery will be established at AEC in the spring of 1991. Species will be evaluated and selected for production potential. Seeds of selected species will be harvested in 1991 and 1992 and multiplied in 1992 and 1993. Reclamation potential of selected species will be field tested in conjunction with native grass lines being developed at AEC (see Native Grass project above)

Status: Project is ongoing and is being co-funded by the Alberta Environmental Centre and the Canadian Parks Service.

3.5 GENERAL

Reclamation of Disturbed Alpine Lands - R. Parker, Hardy BBT Limited

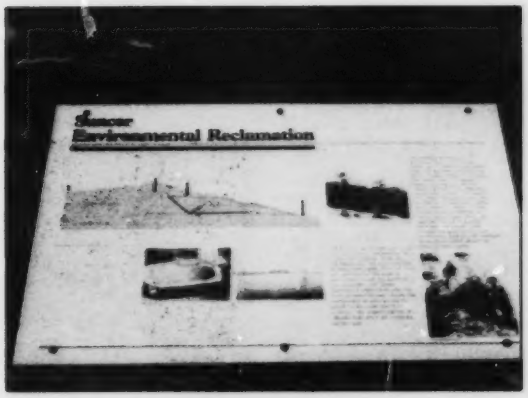
Alpine ecosystems are extremely sensitive to disturbance and will require special efforts if they are to be successfully reclaimed. The objective of this study was to collect information from North American sources and to prepare a report summarizing the measures needed to reclaim alpine disturbances.

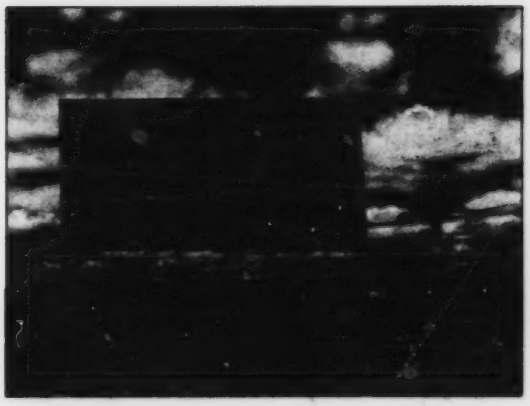
The report outlines: regulations; the alpine setting; current and historic disturbances in the alpine; reclamation methods (planning, site preparation, surface preparation, revegetation, and fertility); and, conclusions and recommendations. The report also pointed out the areas of research needed to fill information gaps for reclamation of alpine disturbances in Alberta.

Status: The project is completed and a final report has been published: RRTAC 90-7. The assistance of the Canadian Parks Service in reviewing the report, and the efforts of Ms. Lilli Chevrier in proofing and reformatting the text, are greatly appreciated.

Native grasses are bathed in a saline solution to determine their tolerance to salts. Several lines were more tolerant than control species used in standard reclamation efforts.

Oil Sands Reclamation Research Program





Members: Chris Powter (Chairman) - Alberta Environment; Lilli Chevrier (Secretary) - Alberta Environment; Tony Dai - Syncrude Canada Ltd.; Al Fedkenheuer - NOVA Corporation of Alberta; Paul Layte - Alberta Environmental Centre; Gary Mann - OSLO; Doug Mead - Shell Canada Resources Limited; Sam Takyi - Forestry, Lands & Wildlife; Steve Tuttle - Suncor Inc.

4. OIL SANDS RECLAMATION RESEARCH PROGRAM

In order to pool resources and avoid duplication of effort, RRTAC and industry initiated a joint research program in 1979. Priority research areas included woody plants (propagation, establishment and management) and soil reconstruction. In 1986, the Program was expanded to include reclamation of tailings pond sludges.

Syncrude Canada Ltd. and Suncor Inc. have been very active supporters of this Program, providing research facilities and funds.

4.1 RECLAMATION OBJECTIVES

1. To develop techniques whereby a self-sustaining, erosion-free cover can be established on oil sand tailings pond dykes; and,

2. To return tailings sand storage and overburden dumps to productive forest and wildlife habitat.

4.2 THE PROBLEM

Northeast Alberta contains all of Canada's surface-mineable oil sands. Extraction of this valuable petroleum resource presents several problems for reclamation. By far, the greatest problem lies with the tailings disposal systems currently employed.

At the end of its 25-year life, a typical oil sand plant producing 19 900 cubic meters per day (125 000 barrels per day) of synthetic crude oil will require a 22 to 31 square kilometre (8.5 to 12 square mile) tailings pond. The liquid contents of the pond will consist primarily of 360 million cubic meters of sludge. The sludge will remain in a liquid state indefinitely and will be impounded behind dykes built of tailings sand. (For more information on tailings ponds the reader is directed to a paper by M.D. MacKinnon in the AOSTRA Journal of Research, Volume 5: 109-133 (1989) titled Development of the Tailings Pond at Syncrude's Oil Sands Plant: 1978-1987 or the Proceedings of the Alberta Chapter, Canadian Land Reclamation Association's 1990 conference on Oil Sands and Heavy Oil Reclamation).

The dykes are built from tailings sand, and will reach heights of 55 to 100 metres above ground level. Erosion protection on the dykes will be provided by a cover of grasses, legumes, trees and shrubs. Because the tailings sand is devoid of nutrients and drains rapidly, amending materials (muskeg, certain mineral overburdens) may be added to begin development of a soil.

Pits left after mining will be filled with tailings sand and overburden dumps will be constructed. These sites will also be reclaimed to a designated land use. Soil reconstruction and woody plant establishment in particular need further research.

4.3 RESEARCH FOCUS

As in the mountains and foothills, proper reclamation in Northeast Alberta will produce landform and plant community combinations which will fulfil their land use requirements without indefinite maintenance.

Work in 1990 continued to identify the best woody species to plant in reclamation areas and to identify the best soil amendments for tailings sand. Methods to enhance freeze/thaw cycles for dewatering tailings pond sludge were also being investigated.

4.4 REVEGETATION AND SOILS

Oil Sands Soil Reconstruction Project - C. Warner, Hardy BBT Limited

Field trials were established on a 7 ha pad of tailings sand prepared by Syncrude Canada Ltd. on their property north of Fort McMurray. Various mixtures of peat and clay were incorporated to 20 and 40 cm depths. In 1984, the plots were planted with tree and shrub species to identify the best soil prescription for a particular forest cover type. Data were collected for five years on tree/shrub survival, growth and spread, and on soil moisture and soil nutrients.

The project was jointly funded with Syncrude Canada Ltd. and Suncor Inc.

Status: The data collection has been completed. A final report will be available in 1991.

Syncrude Tailings Capping Study - C. Warner - Hardy BBT Limited

In the summer of 1990, research plots were designed and constructed on the Syncrude Canada Ltd. mine site at Mildred Lake to test the effect of thickness and quality of replaced soil over tailings sand on the performance of trees and shrubs. Following plot construction, seedlings of four species were planted: jack pine, white spruce, aspen, and dogwood. Baseline height was measured on a random selection of seedlings that were permanently marked for future monitoring. Soil was sampled for thickness, physical, and chemical properties. Results confirmed that plot construction techniques were successful in providing the desired differences among treatments and that monitoring can proceed on the marked seedlings.

The study design consisted of four soil capping treatments (Figure 4):

1. 70 cm "fair quality or better" (T1)
2. 50 cm "fair quality or better" (T2)
3. 30 cm "fair quality or better" (T3)
4. 70 cm "poor quality or better" (T4)

The soil quality ratings are based on the criteria used for determining soil suitability for reclamation in Alberta (Soil Quality Criteria Working Group 1987). Research plots were constructed using current operational methods and equipment.

Status: The project is ongoing.

An Analysis of Vegetation Data from Reclaimed Oil Sands Areas - C. Warner, Hardy BBT Limited

Current methods of revegetating reclaimed areas generally include capping with a peat overburden mixture, seeding with a grass legume mixture, barley nurse crop, or no seeding, and then planting with trees and shrubs.

Normal operational equipment was used to construct the field plots for the capping study in order to ensure the results would be transferable to the field.

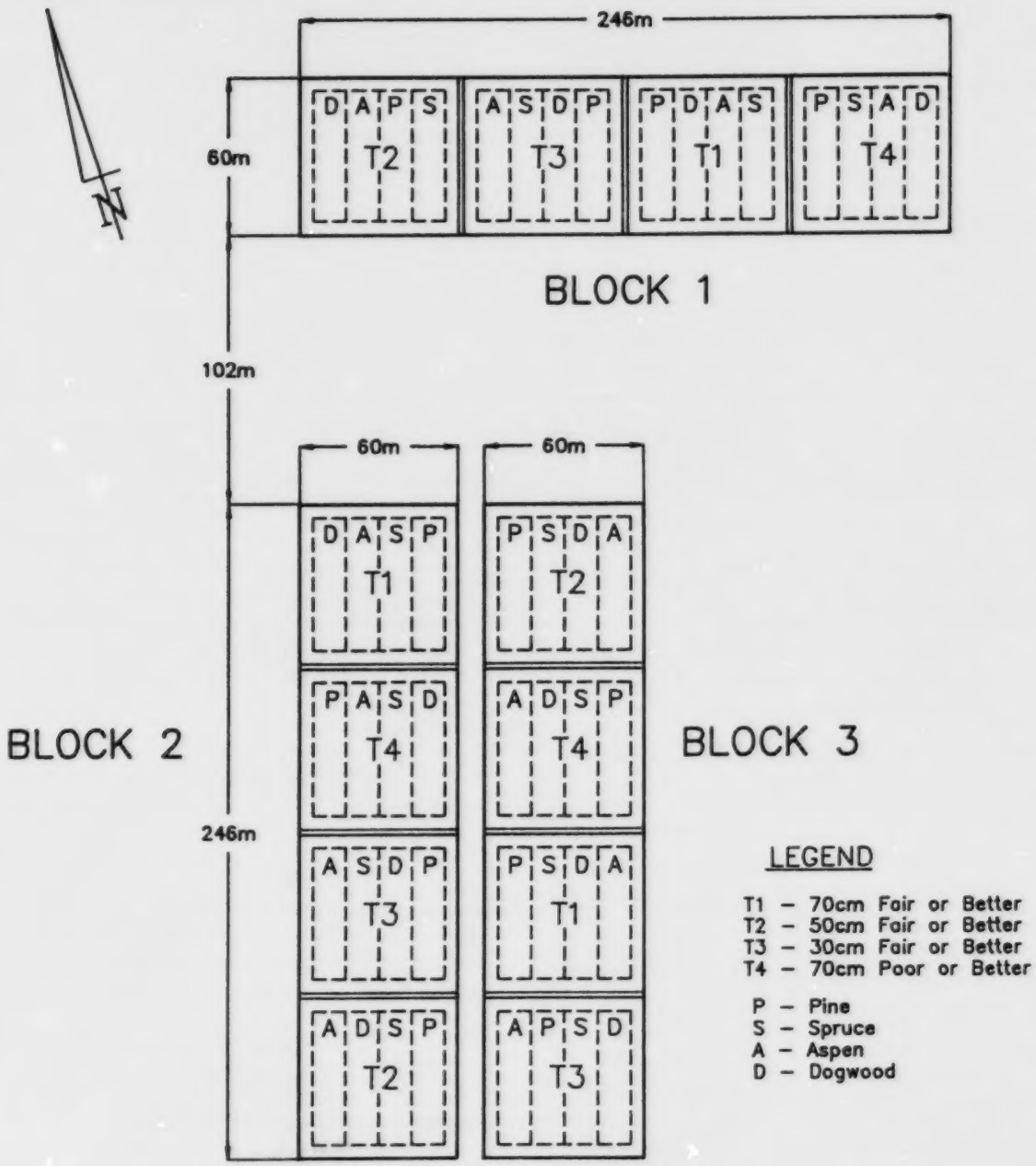


Figure 4. Plot Arrangement for the Tailings Capping Study.

Fertilizer is applied at the time of seeding and for a period of up to three or more years thereafter.

The long-term reclamation goals of these operations are the reestablishment of vegetation communities that are self-sustaining, compatible with the pre-disturbed terrain, and consistent with the end land use of non-commercial forest production providing habitat for wildlife and opportunities for recreation. In addition, an important short-term reclamation goal is providing erosion control, particularly on tailings dyke slopes.

The main objectives of the study were to document the species composition and rate of natural invasion into reclaimed areas and to determine the influence of reclamation methods (seeding, fertilizing, amendment material, etc.) on composition and rate of invasion.

Information was gathered and data reviewed on vegetation establishment in reclaimed areas from both Suncor and Syncrude projects. The data were then synthesized to mean cover values for dominant species on a given site after 1, 5, 10 and 15 years.

Native species composition and rate of establishment for the Syncrude data from the following reclamation sites were compared:

1. Tailings sand seeded to agronomic grasses and legumes,
2. Tailings sand seeded to native grasses and legumes,
3. Tailings sand not seeded (or only seeded to barley),
4. Overburden seeded to agronomic, and
5. Overburden not seeded (or only seeded to barley).

Variations due to peat-overburden ratio were compared using data collected from the RRTAC Soil Reconstruction Project (see above).

Status: The project is completed and a final report has been published: RRTAC 90-3.

4.5 OIL SANDS SLUDGE

Biological Dewatering of Oil Sands Tailings - R. Johnson and P. Layte, Alberta Environmental Centre

Five years of research at AEC and Fort McMurray have established three important facts about the dewatering of oil sands sludges (or fines less than 22 microns in diameter):

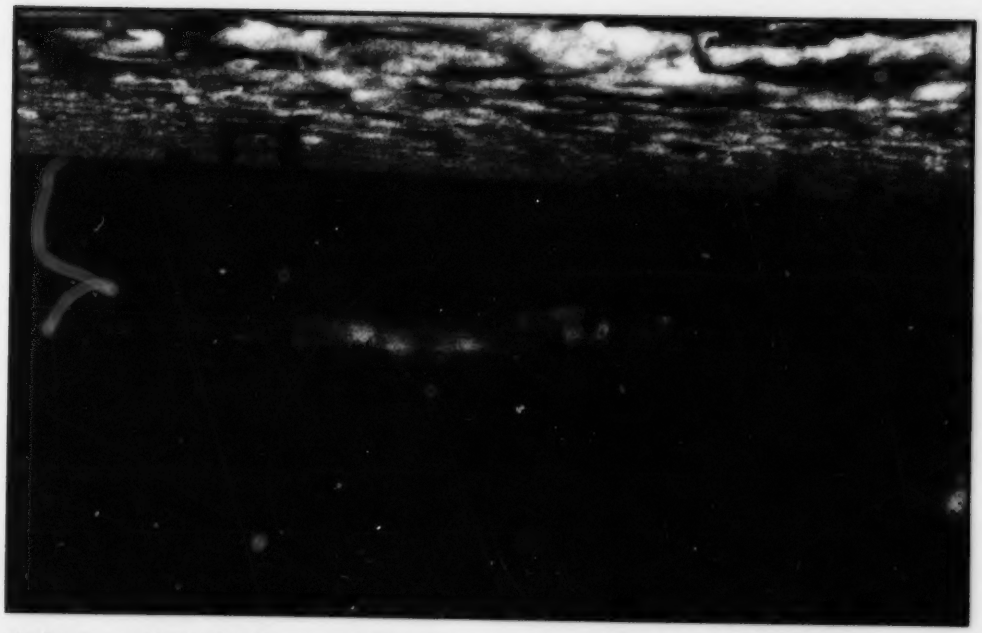
1. it is possible to dewater pure oil sands sludge (as opposed to mixing sand and sludge);
2. freezing and thawing sludge will cause the solids content to increase from 30% to 50% (dry weight basis);
3. reed canary grass can be established on sludge at 50% solids, and the plants will dewater the sludge so that a stable, competent surface results (approximately 80% solids).

Two of three objectives set for the project in 1987 have now been met. First, the amount of dewatering of pure sludge that occurs as a result of freezing and thawing over winter has been established. Dewatering by freezing and thawing is dependent only on the initial solids content.

Second, a surface drainage system for sludges has been constructed that is extremely simple, inexpensive and effective. Furthermore, it has been shown that surface drainage is absolutely essential; if the drainage system does not function properly and water is allowed to accumulate on the surface, originating from the thawing process or precipitation, plants will not establish and dewatering does not occur.

The third objective was to compare dewatering by plants (evapo-transpiration) and by evaporation alone. Due to the malfunction of the first attempts at surface drainage, this comparison has not been made. It is obvious, however, that dewatering by plants is faster and much deeper when the plants are established in the early summer (late May in Fort McMurray).

Both pure sludge, starting at 30% solids, and sand-sludge mixes, starting at 50% solids, have been successfully dewatered using a com-



Sludge, poured in the fall, freezes and thaws, releasing water (background) and consolidating the solids (foreground). Removal of the water is critical to the success of the dewatering process.

bination of freezing and thawing, evaporation and evapotranspiration. The surfaces can now support the pressure of equipment traffic. Volume reduction as a result of dewatering varies according to the starting materials. For the pure sludges, the final volume is only 35 to 40% of the original; for the sand-sludges mixes, the final volume is 65% of the original. The difference is due, of course, to the different amount of water contained in the two materials initially and the water loss during freezing and thawing and evapo-transpiration.

Reed canary grass has been shown to be hardy; it will overwinter in northeastern Alberta while growing on oil sands sludge.

Status: Work is ongoing at AEC. A final report on the work to-date will be completed in 1991.

Evaluation of Sludge Dewatering Techniques - A. Sethi, McMurray Resource (Research and Testing) Ltd.

The general objective of the project is to determine if natural dewatering processes for oil-sands sludge can be practically applied:

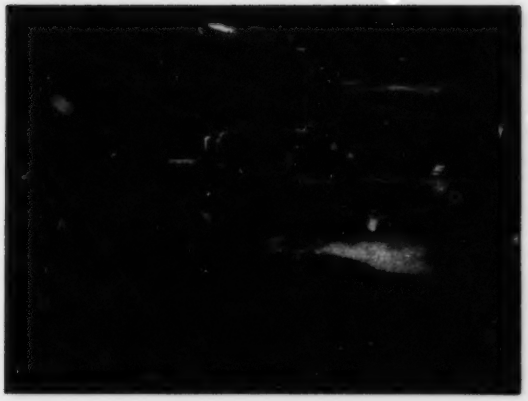
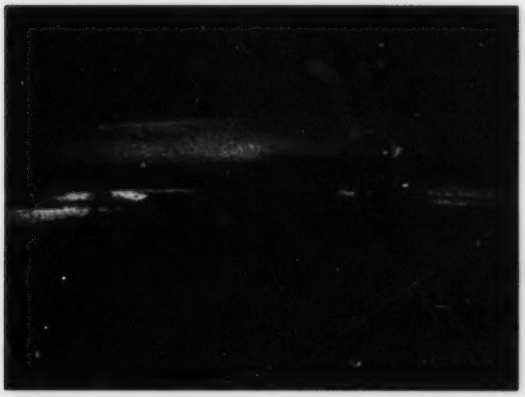
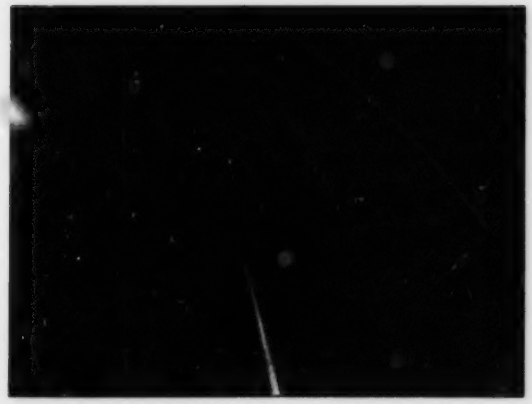
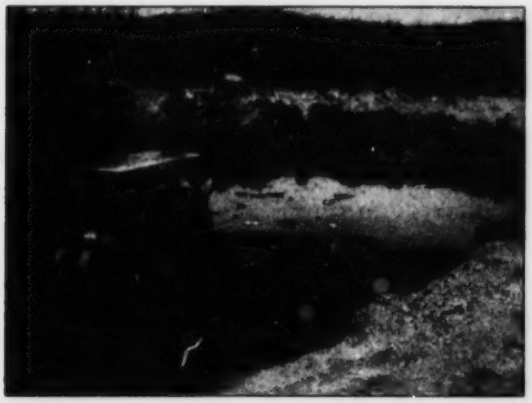
1. to significantly reduce volumes of sludge that have to be stored in Tailings Ponds,
2. as part of a sludge dewatering process that would result in reclamation of sludge as "dry material",
3. to develop a reclamation surface for tailings ponds and mine pit areas that would inhibit erosion and infiltration of surface water.

Specific objectives include:

1. To evaluate the potential for freeze/thaw processes to work on sludge applied in a single, deep pit.
2. To evaluate the potential for freeze/thaw to work when sludge is applied in a series of thin layers from an outside pit.
3. To evaluate the potential for freeze/thaw to work when sludge is applied in a series of thin layers when pumped from the bottom of a deep pit.
4. To evaluate the potential for freeze/thaw to work when sludge is applied in a series of thin layers and layers of sand are applied.

Status: Project is ongoing and is being co-funded by Suncor Inc.

Oil and Gas Reclamation Research Program

Members: Chris Powter (Chairman) - Alberta Environment; Lilli Chevrier (Secretary) - Alberta Environment; Richard Coleman - Alberta Environmental Centre; Roger Creasy - Energy Resources Conservation Board; Al Fedkenheuer - NOVA Corporation of Alberta; Jim Fujikawa - Alberta Environment; Arnold Janz - Alberta Environment; Al Kennedy - Esso Resources; Leon Marciak - Alberta Agriculture; Doug Mead - Shell Canada Resources Limited; Gary Mott - Bow Valley Industries Ltd.; Sam Takyi - Forestry, Lands & Wildlife; Wayne Tedder - Forestry, Lands & Wildlife.

5. OIL AND GAS RECLAMATION RESEARCH PROGRAM

Conventional oil and gas deposits are found in all three biophysical regions noted above, while heavy oil deposits are found in the northeast. Since these disturbance types create similar reclamation concerns (disposal of drilling wastes, compaction, soil handling, residual herbicides) regardless of biophysical region, a separate program was developed to co-ordinate research.

There are more than 130 000 wellsites and over 200 000 km of pipelines in the province, indicating the need for a strong research program in this area.

5.1 RECLAMATION OBJECTIVES

The Oil and Gas research program addresses reclamation of all types of oil and gas facilities, including: wellsites, on- and off-site drilling waste sumps, access roads, compressor stations and batteries, and pipelines. Specific reclamation objectives are:

1. To develop environmentally-safe methods for disposal of drilling wastes (fluids and solids); and,

2. To return land to a condition capable of sustaining an approved land use.

5.2 THE PROBLEM

5.2.1 Drilling Wastes

Three basic drilling muds and variations thereof are used for oil and gas exploration in Alberta. The freshwater gel bentonite is most commonly used followed by the salt water systems which use sodium or potassium. The oil invert drilling mud is also used and is gaining in popularity with some companies. Diammonium phosphate (DAP) mud is being used in the Cold Lake region.

The wastes produced from drilling operations contain many complex organic and inorganic compounds that are added at various stages of the drilling process. The materials that start out as drilling mud are usually extensively altered chemically and physically by the time they enter a waste pit. The muds can be altered by heat and pressure effects associated with drilling and by the addition of drill cuttings (rock) brought up with the mud system. The materials found in the waste pit can also be changed chemically and physically by other products that are purposely or inadvertently added to the pit. Caustic soda, rig wash, diesel fuel, waste oil from machinery, metal and plastic containers, and other refuse often find their way into a waste pit.

The physical location of the waste pits must be carefully chosen to minimize the potential for subsurface spread of leachates that may be generated from the drilling wastes. Knowledge of site characteristics such as: (1) the distance between the disposal site and the nearest surface water body, groundwater supply, or other designated boundary, (2) the depth to the watertable, (3) the water table gradient away from the site, and (4) the type and thickness of geologic material through which the contaminated water could migrate is required to make decisions on the suitability of a waste pit location. Knowledge of proposed waste pit contents and their likely effects on the permeability of pit liners is also important.

Drilling wastes are currently disposed of by burying, trenching, squeezing, and spreading. Each of these disposal methods impacts the environment in different ways. For example, direct interactions of waste constituents with groundwater is much more likely to occur if wastes are trenched or buried as opposed to surface spread. The reverse is true for soils and plants.

Review of the literature indicates that effects of disposal of drilling wastes on plants and soils varies with the type of waste, rate of application and plant species.

A thorough physical and chemical analysis of the liquid and solid phases of wastes generated by drilling operations utilizing the different mud types is one of the prerequisites to assessing the potential environmental hazard of the disposal of these wastes and developing environmentally safe disposal methods.

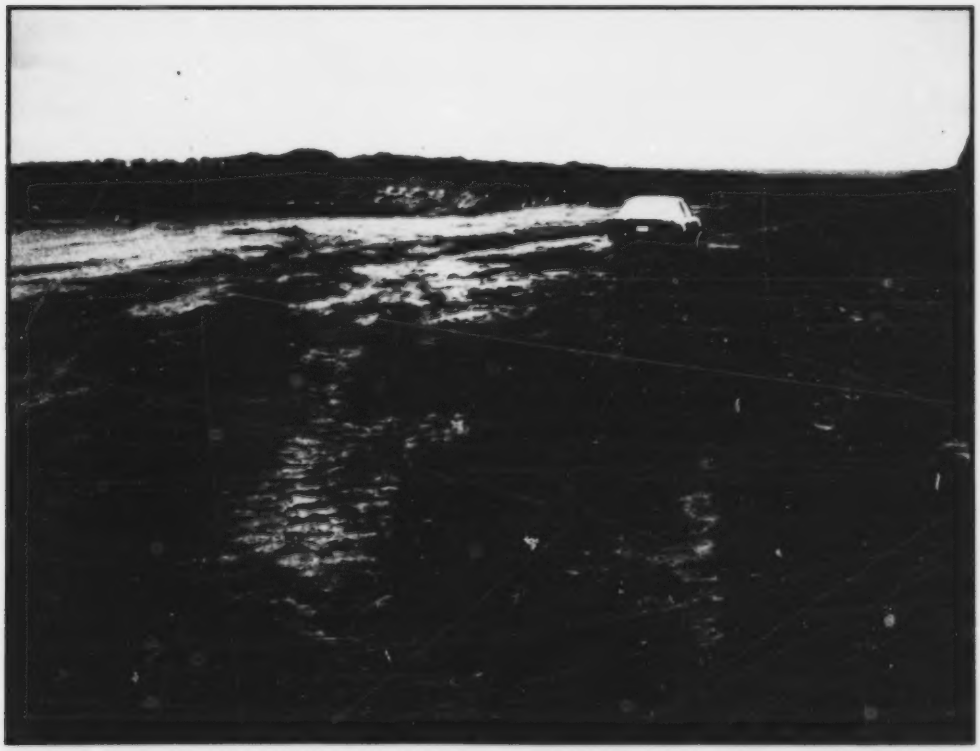
5.2.2 Compaction

Mining, pipelining and the construction of oil and gas leases all have dramatic effects on soil compaction. In fact, a report by the United States Office of Technology Assessment found that soil compaction was the single biggest problem in reclaiming cropland disturbed by mining. A survey conducted by RRTAC found that Reclamation Officers perceived soil compaction to be the prime concern in reclaiming oil and gas wellsites.

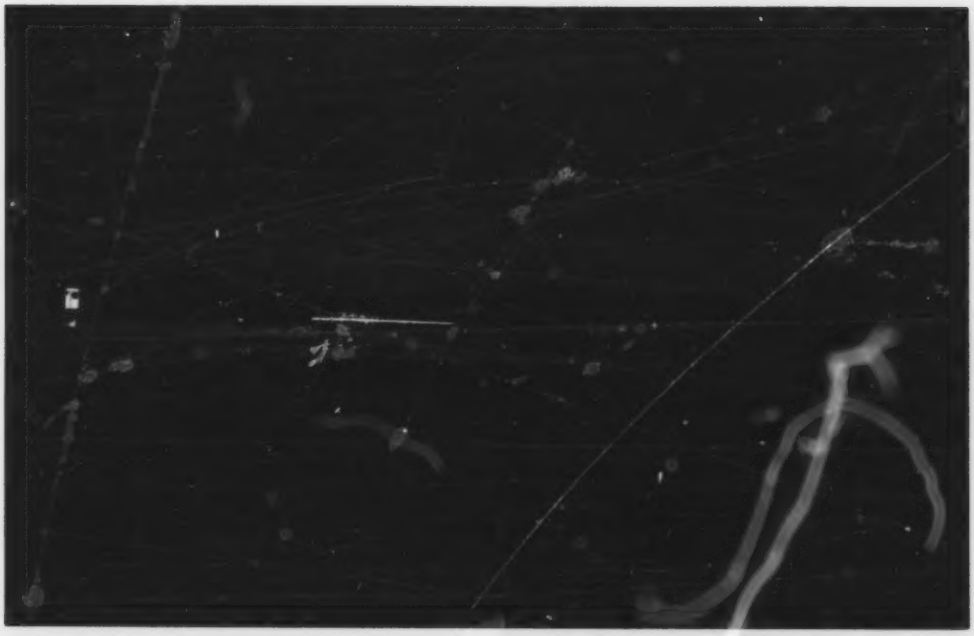
Repeated passage of heavy equipment during development and operating phases of a wellsite results in compaction of the soil. Compacted soil retards root development which can lead to moisture and nutrient stress in plants. This, in turn, retards shoot development and yield. Freeze/thaw and wetting/drying cycles were thought to loosen compacted soil, but there is considerable debate about whether this occurs, or at what rate it occurs. In Alberta, moderately compacted soils can have recovery times measured in decades; high clay contents are associated with long recovery times.

There is a lack of useful data pertaining to soil compaction in Alberta (and elsewhere), largely because a fully satisfactory measurement has yet to be identified. Crop yield is the best measure of compaction in addressing agricultural concerns. However, the effect of soil compaction on crop yield varies with soil type, yearly meteorological conditions, and type of crop. A measurement of compaction must be identified that has a high correlation with plant response, is independent of soil type, is inexpensive, and can be performed rapidly.

Bulk density is most commonly used to determine soil compaction but shows considerable natural variation due to soil particle size distribution and organic water content, and has no unique value at which root growth is impeded. Hydraulic conductivity, porosity, air permeability, infiltration and sorptivity yield valuable information about the effect of compaction on physical processes in soils. But these measurements are not used widely due to long measurement times, wide data variability, departure from normality and the absence of an exact relationship between these properties and plant growth.



Compaction of soil by heavy equipment may cause future problems for plants and water movement on the site.



Soil sterilants are used to remove vegetation from industrial sites for a long period of time. However, when the site is no longer required, the sterilants must be inactivated to allow for revegetation. In addition, as shown here, the sterilants may move off the original site.

A hand penetrometer, developed at the Alberta Environmental Centre, allows mechanical impedance to be measured at various depths in the field at extremely low cost. Now, Reclamation Officers are equipped to measure compaction at any disturbed site. However, there is little information relating mechanical impedance or any other measurement to reductions in crop yield in Alberta. What is needed is a simple model for routine applications that predicts plant yield with a minimum of data input.

It is important to note that while wellsites were chosen for evaluation of compaction problems, any disturbance that involves the use of heavy equipment can produce compaction. Thus, the results of this research may be applicable to pipelines, highways, mines, sand and gravel pits, and forestry skid trails and loading zones, among others.

5.2.3 Residual Herbicides

Soil sterilants, residual herbicides that render the treated soil unfit for plant growth for relatively long periods of time, are used in Alberta on wellsites, rights-of-way and other industrial areas for total vegetation control. Such vegetation control measures reduce fire hazards and improve aesthetic appearance. The treated areas can remain devoid of vegetation for many years depending upon the type and rate of soil sterilant used and the soil and climatic conditions. Furthermore, it is not uncommon to use more than the recommended rates of these chemicals for achieving long-term vegetation control with a single application. Bromacil and tebuthiuron are commonly used soil sterilants in Alberta.

Once the sterilant-treated site is abandoned, it may take several years before the site is restored to its original capability. The site also becomes a potential source of contamination through surface runoff and wind dispersion of soil sterilants onto adjoining untreated land. In Alberta, the extent of the soil sterilant prob- lem is becoming apparent as more oil and gas lease sites are abandoned due to the marginal production value of many wells. The seriousness of the problem has been identified by various provincial organizations and committees.

5.2.4 Pipelines

Construction of pipelines results in the excavation and replacement of soil to a depth of more than a metre along a long, narrow right-of-way through a variety of soil types. Each soil type requires special soil handling methods to ensure that it can be returned to provide equivalent soil capability.

Research is required to identify the best soil handling methods for individual soil types or groups of soils. There is also a lack of information regarding the best methods to handle soils in the sensitive drier areas of the province where vegetation is difficult to re-establish.

5.3 RESEARCH FOCUS

In 1984, RRTAC sponsored a two-day workshop on drilling waste disposal in Alberta (Report 87-3). The workshop identified a number of concerns that needed to be addressed. As a result of this workshop, our initial research focused on trying to develop a manual that could be used by field staff to determine whether a waste could be safely spread on a given soil surface (Report 87-1). The manual pointed to a need for detailed chemical characterization of sump fluids and solids before rational disposal decisions could be made (Report 89-6). Work in 1990 concentrated on revising the original field disposal manual, getting more data on sump chemistry, and evaluating the optimum rates for land disposal of invert drilling wastes.

The approach to the residual herbicide problem was to identify methods for binding the herbicide, thus rendering it ineffective (Report 89-3). Work in this area in 1990 focused on determining the scope of the problem in Alberta, and setting up a field experiment to extend the lab work completed previously.

Pipeline research focused on providing a forum to discuss soil handling issues, evaluating methods for reclaiming pipelines in southern Alberta, and evaluating methods for collecting soils information in the winter.

5.4 DRILLING WASTES

Update of the Drilling Waste Disposal Manual - T. Macyk, Alberta Research Council

The objective is to revise and update the existing RRTAC field manual (Report 87-1) prepared to assist industry and government field staff in the planning and implementation of environmentally sound methods for surface disposal of drilling wastes.

The researchers obtained comments on the original report from government and industry staff, and revised the original manual, specifically by:

1. developing a more definitive drilling waste disposal decision flow chart,
2. developing a glossary or simplifying terminology used in the manual,
3. indicating what parameters could be tested in the field, why they should be tested, and the appropriate procedures to be used,
4. redefining the calculations to determine sump contents; providing critical levels for parameters so that calculations are completed,
5. condensing and clarifying the checklist for fieldmen,
6. expanding on the guidelines for obtaining representative samples, and
7. developing a computer program that will allow users to do the calculations prescribed in the manual.

The study is being coordinated as much as possible with work ongoing in the government/ industry Drilling Waste Review Committee that has responsibility for updating the existing drilling waste guidelines (see next project).

Status: The project is ongoing and is being co-funded with the Alberta Research Council.

Landfarming of Invert Drilling Wastes - T. Macyk, Alberta Research Council

Diesel fuel forms the liquid portion of invert drilling muds rather than water. Therefore, the organics in the waste may be bio-degradable in the soil, and landfarming of this type of drilling waste may be an environmentally sensible option. This objective of this study is to develop an environmentally acceptable land application rate of invert mud drilling wastes for soils in Alberta and to model the fate of these wastes. The sub-objectives include:

1. measurement of the rates of degradation of the invert mud drilling wastes in soil at different waste concentrations, frequencies of application, and soil temperature;

2. measurement of the relative impact of oily materials and salts present in the wastes on soil quality and plant growth in a greenhouse pot experiment; and,

3. assessment of the impact of different application rates and frequencies of application of invert mud drilling wastes on soils and vegetation in a field experiment.

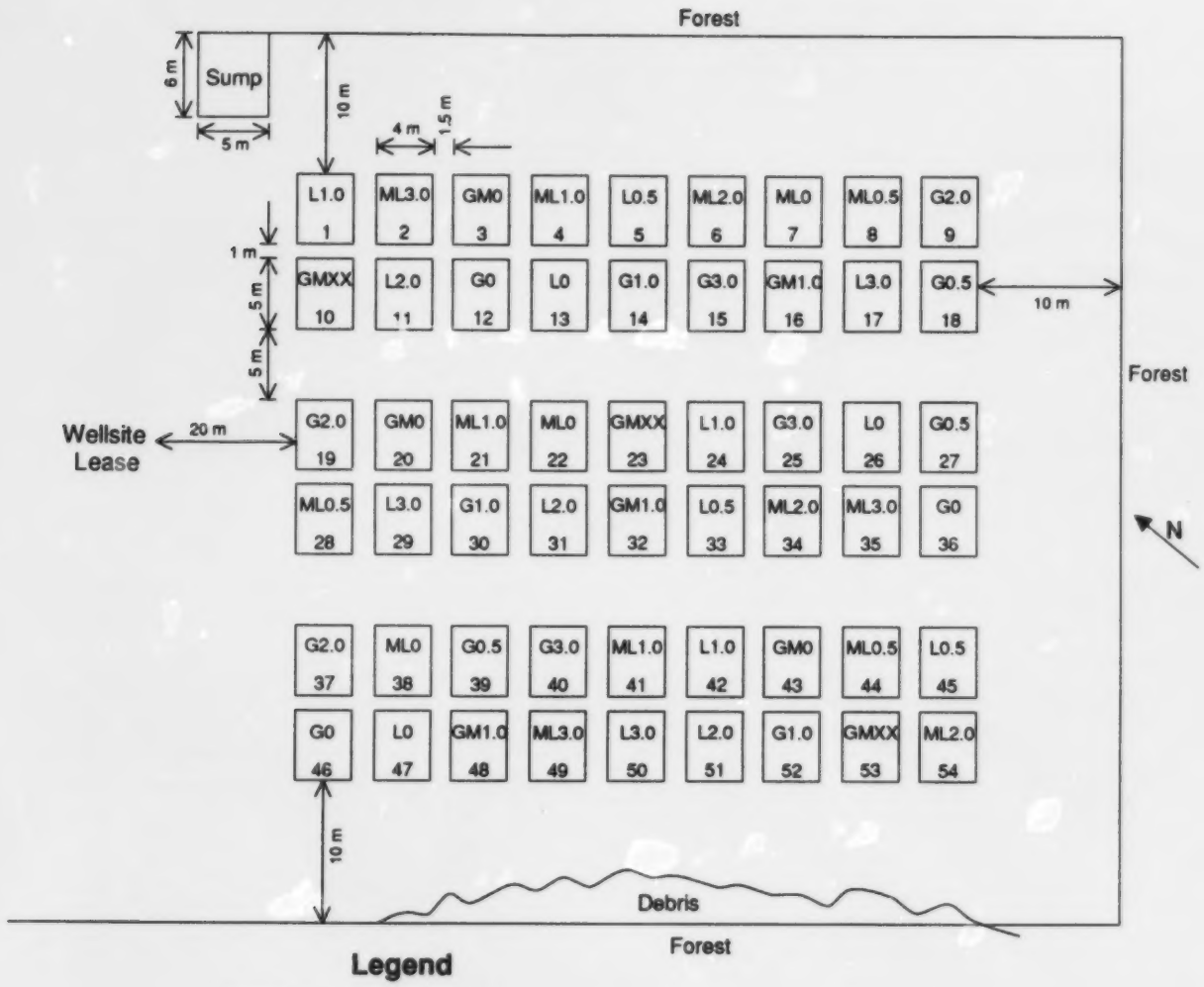
The field experiment was established in 1990. Fifty-four plots were set up to evaluate 5 rates of invert application (based on oil content) and three vegetation types (none, brome grass, and a grass/legume mix) (Figure 5). Petro-Canada has supplied the invert waste and a field location for the research near Edson. Local Alberta Forest Service officials have also been very helpful in the project.

Status: The project is ongoing and was co-funded by the Alberta Research Council.

CPA Sump Chemistry Study - T. Macyk, Alberta Research Council

A joint government and industry task force is currently updating the existing guidelines/criteria for disposal of drilling wastes in Alberta. The Drilling Waste Review Committee decided that a sump sampling and analysis

Research plots for the landfarming experiment being prepared. Incorporation of the invert waste into the soil is critical for the success of the treatment.



Legend

L1.0 / 1 - Treatment (no vegetation, single oil application of 1.0%) - Plot number

G - Brome grass, single oil application
GM - Grass mixture, single oil application
GMXX - Grass mixture, no oil application
L - No vegetation, single oil application
ML - No vegetation, multiple oil application

Figure 5. Plot Layout for the Diesel Invert Study

Both the liquids and solids were sampled and analyzed from drilling waste sumps throughout the province. Specialized sampling equipment was developed by Nor-Chief Consulting Services (1978) Ltd.

project was required to allow for characterization of a cross-section of drilling wastes from sumps throughout Alberta. The data from this study will enhance the work already done by RRTAC and the Alberta Research Council (Report 89-6) and will provide a basis for the criteria that are ultimately developed.

The objective of Phase I of this project was to design a study for the characterization of a cross-section of drilling wastes from sumps throughout Alberta. The study design included a number of specific components:

1. Sampling, including: number of sumps to be sampled; locations to be sampled; types of wastes to be sampled; and, sampling protocol.
2. Characterization, including analyses to be conducted and, methods specified for each analysis.
3. Building of database.
4. Data synthesis and interpretation.
5. Report preparation.

Phase II, funded entirely by industry at a cost of $585,000, involved the sampling of 114 sumps throughout the province and the analysis of solid and liquid phases samples from each sump, as well as some samples of mud makeup water.

Phase III, funded by RRTAC over 1990/91 and 1991/92, will cover the write-up of the data.

Status: The project is ongoing and is being co-funded by the Alberta Research Council and the oil and gas industry. A final report will be available in 1991.

Literature Review on the Environmental Acceptability of Drilling Waste Burial - T. Schori, Monenco Consultants Limited

Drilling waste solids may be disposed of in several ways: burying, trenching, squeezing, and landfarming. There has been a movement

within some sectors of the government away from burying in sumps as a disposal option because of concerns about potential for migration of contaminants into groundwater.

The objective of this project was to review the international literature to determine the environmental acceptability of burial of drilling waste solids produced during petroleum exploration.

One of the major tasks was to define, to everyone's satisfaction, the term burial, and the various forms it may take. The report outlines the regulatory framework for drilling waste disposal in Alberta, Canada and the United States.

Burial is generally thought to be acceptable for most drilling wastes, however each site/waste combination must be evaluated on a case-by-case basis, and the appropriate regulatory agencies contacted for final approval of the selected option. Burial is not an option for invert wastes.

Status: The project is completed and a final report has been published: RRTAC 90-9.

5.5 COMPACTION

Compaction on Oil and Gas Leases (Phase I) - N. Finlayson, CAN-AG Enterprises Ltd.

This field survey project addressed four compaction concerns on east central Alberta oil and gas wellsites:

1. The suitability of various methods of measuring compaction (soil strength, bulk density, morphology, porosity, pore size distribution) with regard to their sensitivity in detecting compaction, the number of samples necessary to adequately assess compaction, the time and cost involved, and the skill, equipment or facilities necessary to use the technique;

2. The extent of soil compaction, both vertically and horizontally;

3. The degree of soil compaction on oil and gas well lease sites as compared to adjacent off-site areas; and,

4. The nature of soil compaction with respect to how various soil properties are affected by the compaction process.

To accomplish these goals, a two-stage survey was conducted. A detailed survey concentrated on establishing appropriate sampling densities and on evaluating various techniques of measuring compaction. At five wellsites, data were collected on soil strength (recording penetrometer), undisturbed cores were collected for measurement of bulk density and pore size distribution, disturbed or undisturbed cores were collected for measurement of moisture content, texture and organic matter, and soil profiles (for classification) and soil morphology (for the morphological compaction classification technique of McKeague et al.) were recorded.

The second part of the survey involved an assessment of soil compaction on 20 wellsites using a recording penetrometer to measure vertical and horizontal soil compaction profiles. Emphasis was placed on strength measurements because they can be taken quickly, no expensive and time consuming laboratory work is required, and work at the Alberta Environmental Centre and elsewhere suggests that soil strength may be the variable most closely related to plant growth in compacted soils.

The information generated by this research should better determine the nature and scope of the compaction problem and will establish appropriate methods and sampling designs for future work concerning compaction on Alberta oil and gas leases.

Status: This phase of the compaction work is completed and a final report is in preparation.

Compaction on Oil and Gas Leases (Phase II) - Milner Engineering

The main objective of this research is to identify the relationship between subsoil compaction, topsoil depth and plant productivity under a range of conditions (soils and years). The experiment is factorial and arranged in a completely randomized design, with three compaction levels (no compaction, medium, and heavy compaction) spanning the range of levels

Assessing penetration resistance (a measure of soil compaction) on the plot with 5 cm of topsoil and the highest level of compaction (i.e., the worst case plot).

found on wellsites, and four topsoil levels (5, 20, 35, and 50 cm depth). A 30 cm thick layer of compacted subsoil is used in each plot; 30 cm thick compacted layers have been documented on wellsites in Alberta, and heavy agricultural traffic is capable of compacting soils to more than twice this depth. For each subsoil compaction level, four depths of topsoil cover are used: 5 cm, 20 cm, 35 cm, and 50 cm. These depths provide a range of conditions: from too little soil to support a crop, even under ideal moisture and nutrient conditions, if subsoil compaction is severe; to sufficient topsoil to support a full crop, regardless of subsoil compaction, under all but the most limiting moisture conditions. The minimum depth is chosen to ensure seedling establishment; the maximum depth is an upper limit of topsoil available for reclamation under any conditions.

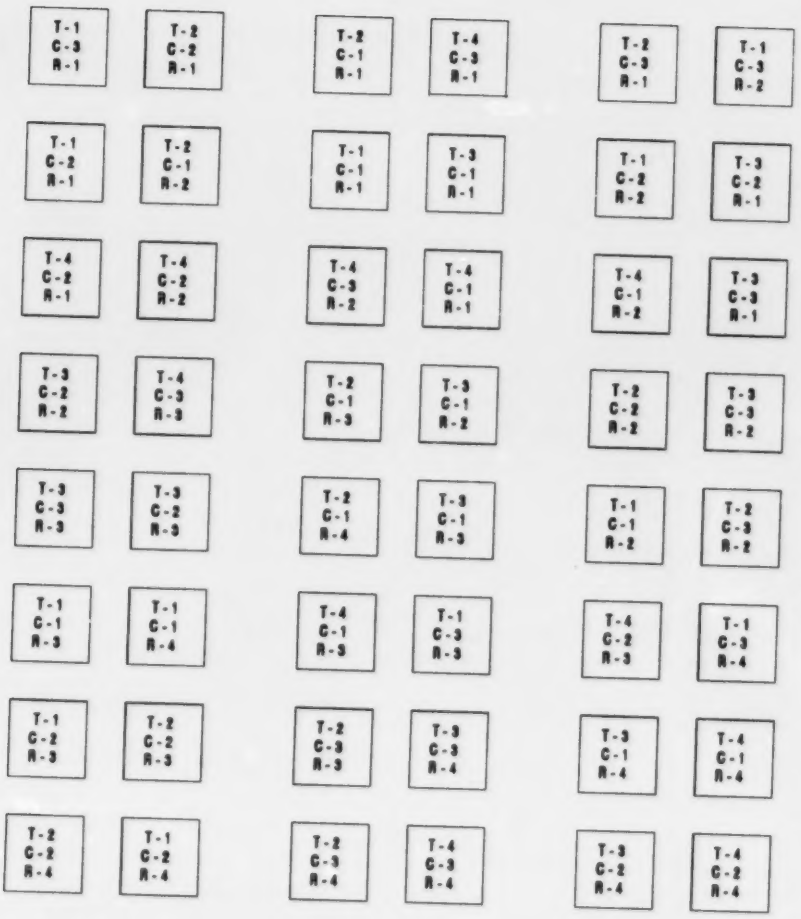
Each treatment is replicated four times at each of two sites: a Chernozem soil in Vegreville (Figure 6), which was constructed in 1989; and a Luvisol near Myrnam (Figure 7), which will be constructed in 1990. This gives a total of 96 plots.

Barley is being grown in each plot for three years, and the growth response (measured by root biomass, root length, shoot biomass and crop yield) will be related to three measures of soil compaction (penetration resistance, bulk density and porosity). Barley has been selected as the test crop based on its widespread cultivation in Alberta, its high salt tolerance (preventing any salt effect from becoming the limiting factor to plant growth) and its use as a monoculture on small plot areas for several years without significant problems. Additional species would undoubtedly provide additional information but would result in a prohibitively large experiment.

The null hypotheses for the study are:

1. The degree of subsoil compaction does not influence barley growth or productivity (as measured by yield, biomass, or rooting characteristics) in fine-textured soils.

2. Barley growth and productivity on compacted, fine-textured soils is independent of topsoil depth.



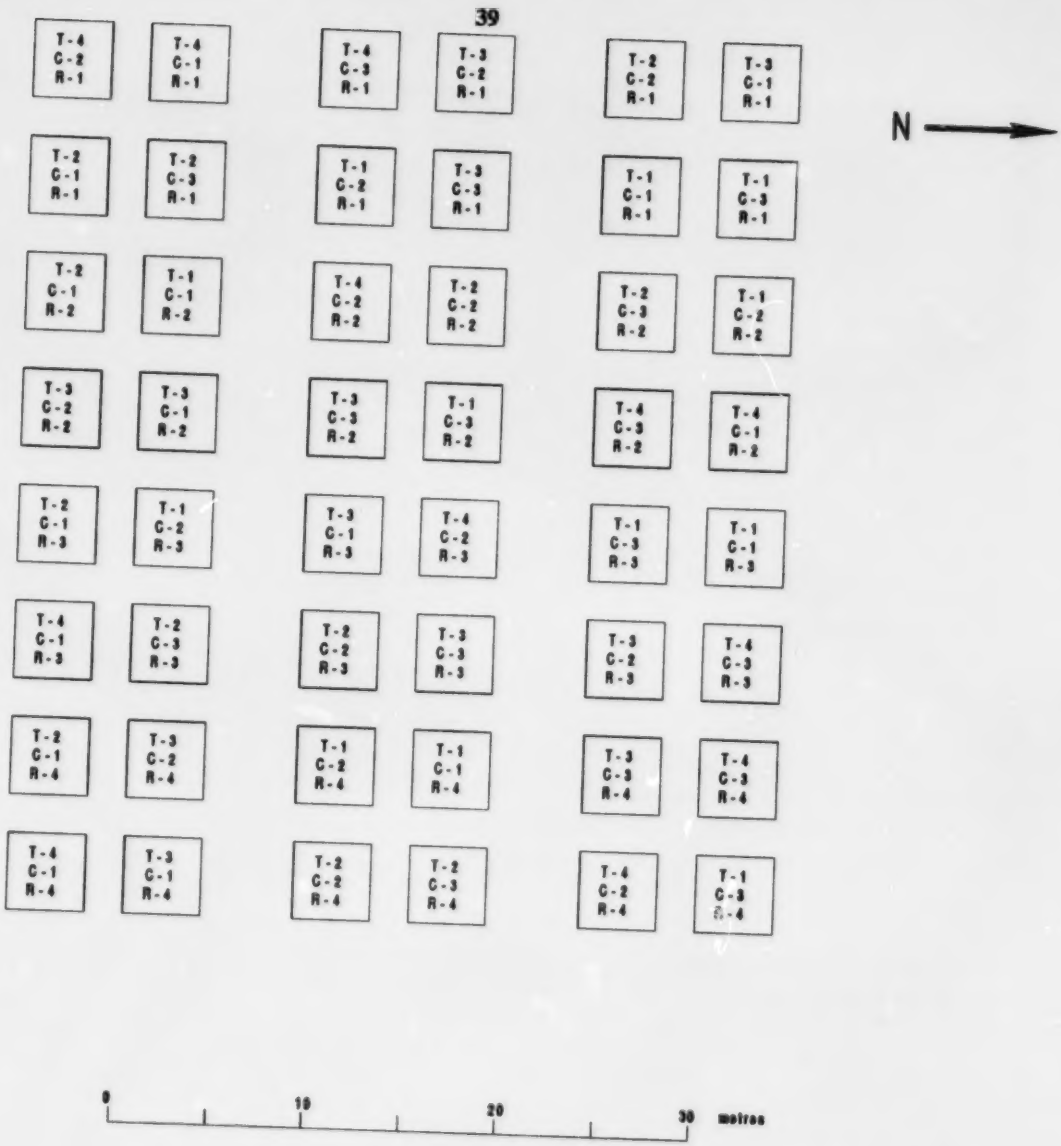
LEGEND

T indicates topsoil depth, where 1 = 5cm, 2 = 20cm, 3 = 35cm, 4 = 50cm.

C indicates compaction level, where 1 = no compaction, 2 = moderate compaction, 3 = heavy compaction.

R indicates replicate number.

Figure 6. Compaction Plot Layout at the Chernozemic site (Vegreville)



LEGEND

T indicates topsoil depth, where 1 = 5cm, 2 = 20cm, 3 = 35cm, 4 = 50cm.

C indicates compaction level, where 1 = no compaction,
2 = moderate compaction, 3 = heavy compaction.

R indicates replicate number.

Figure 7. Compaction Plot Layout at the Luvisolic site (Myrnam)

3. The relationship between barley growth and productivity, and subsoil compaction is independent of soil type (Chernozem or Luvisol).

4. Barley growth and productivity on compacted, fine-textured soils is independent of climate (year).

5. There are no interactions between subsoil compaction, topsoil depth and climate (year) that influence barley growth or productivity on compacted, fine-textured soils.

6. Soil strength, bulk density and pore-size distribution are equally accurate in predicting barley growth and productivity in compacted, fine-textured soils.

It is anticipated that three years of data will be sufficient to analyze plant response under different growing season conditions. If this time period proves to be insufficient, the study may be extended.

Status: The project is ongoing and is being funded by the Alberta Environmental Centre. More information is available from the Centre.

5.6 STERILANTS

Sterilants Issue Scoping - M. Cotton, Wild Rose Consulting Inc.

The project was initiated in June, 1990 with objectives to assess the issue of the soil sterilant problem in Alberta and suggest a research program that would ultimately lead to the development of a procedures manual for the reclamation of sterilant affected sites. The research procedures involved the review of literature and extensive discussions with government, industry and research personnel.

From the information obtained from the industry and government personnel it was not possible to estimate the number of sites currently affected by sterilants because most estimates were qualitative only and varied greatly depending upon the source of information. However, on the basis of the number of oil and gas wells either operating (50 000) or capable of operating (73 000) and gas plants (500) in the province, and the documented use of soil sterilants in the Green Area of Alberta, it is estimated that there may be as many as 61 750 sites affected by soil sterilants.

Bromacil and tebuthiuron were the most commonly used soil sterilants in the past and require immediate attention for reclamation of affected sites. However, the use of atrazine and diuron and two other selective residual herbicides, chlorsulfuron and picloram, has been increasing in the past few years. A description of each herbicide is provided in the report.

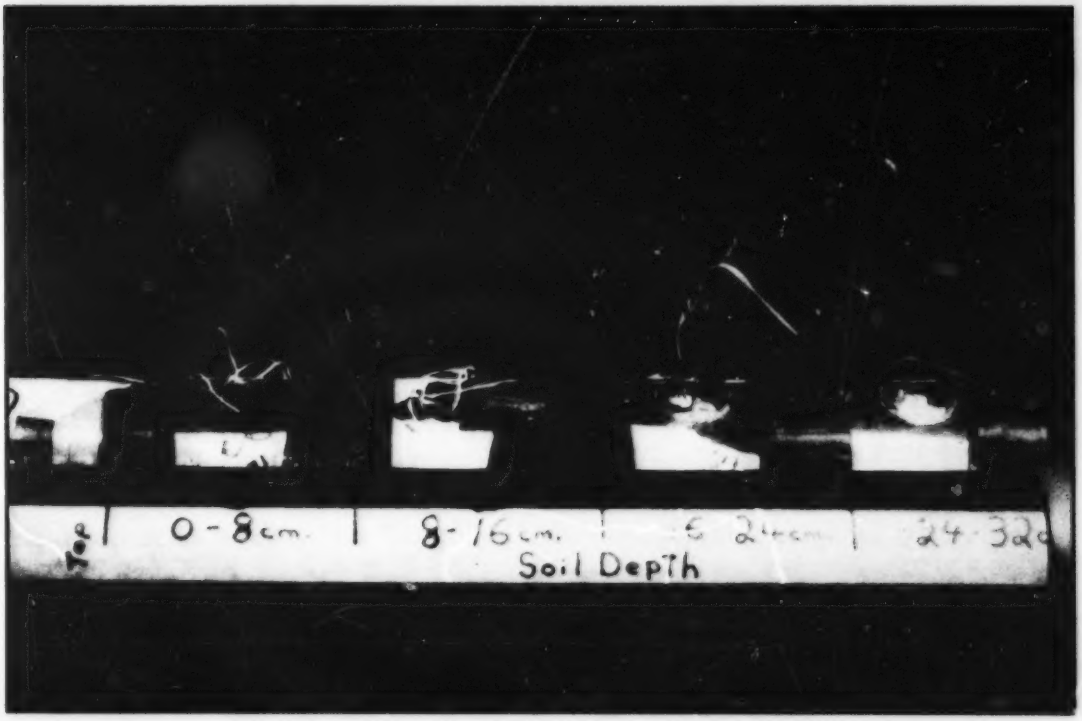
The most common method practised in the industry for reclamation of sterilant affected sites involves the use of manure and other organic material such as straw and peat with cultivation. However, this method gives only marginal results and usually takes 3 to 5 years to be effective. A second method that is commonly known, but not commonly used involves the incorporation of activated charcoal usually in combination with manure. The report outlines methods for assessment of sterilant affected sites including detailed information on soil sampling and methods of herbicide residue analyses involving chemical analyses and plant bioassays. A list of private laboratories involved in pesticide analysis is provided.

Based on the concerns of government and industry related to the reclamation of sterilant affected sites, a research program is outlined for further investigation. This includes projects to study: (1) persistence, leaching, and movement into groundwater of soil sterilants; (2) Development of techniques for reclamation; and (3) Impact of soil sterilants on soil characteristics.

Status: Project is completed and a final report will be available in 1991. The project was co-funded by the Alberta Environmental Centre.

Development of Reclamation Techniques for Soils Contaminated with Sterilants - M. Cotton, Artemis Consulting Inc.

A cooperative project involving Esso Resources Canada Limited, the Alberta Environmental Centre, and RRTAC has been initiated to develop techniques and recommendations for effective reclamation of soils treated with residual herbicides. The objectives of this project are:



A tube sampler, shown above, was developed by AEC staff to assess the depth to which sterilants were affecting crop growth. In this sample, the sterilant is active to at least 16 cm depth. In other areas of the site, however, sterilants have been detected below 1 metre.

1. To analyze soil samples from sterilant affected sites to assist in planning reclamation strategies.

2. To examine the effectiveness of activated charcoal and manure (alone and in combination), sawdust, and three commercially available microbial or organic products under field and controlled environmental conditions.

3. To investigate the influence of herbicide and amendment ratios, soil type, number of incorporations, and fall and spring applications on the effectiveness of the amendments listed in objective 2.

Four sites have been evaluated and selected for their potential use in field research. One site is located at the Alberta Environmental Centre research facility in Vegreville, the remaining three are in the Devon area, and are currently owned by Esso Resources Canada Limited.

The Devon locations were selected because they have been treated with soil sterilants, and they are large enough to allow for the establishment of plots. Devon is an older field and it will be experiencing quite a number of decommissioned sites over the next few years. Research at these locations will be beneficial to a number of companies. Such sites may be affected by other contaminants such as hydrocarbons, salts and industry chemicals that can affect the reproducibility of the study, therefore the Vegreville site was established to provide a field location that can be kept under relatively controlled conditions. The Vegreville site was set up in the fall of 1990 to examine three rates of bromacil and of tebuthiuron (0, 2, 6 kg/ha).

Eight to ten core samples plus a control were taken to a 60 cm depth at each of the Devon locations. A comparison between 10 cm and 15 cm increments was conducted on two of the samples from two of the sites to determine if there was difference in residue distribution in

the soil profile. The soil was collected from the Vegreville location and treated with 0, 2, 6 kg/ha of bromacil and tebuthiuron.

Initial site fertility and physical analyses have been completed and a sterilant scan of composite samples has revealed the presence of diuron on all three Devon sites, as well as possible trace amounts of bromacil at one location and atrazine at another. Results of growth chamber bioassays have indicated the presence of picloram residues on two of the Devon sites. Further analyses of individual core samples are being conducted.

Growth chamber experiments to examine the effectiveness of the various amendments on the inactivation of herbicide residues have been set up on soil samples from the Devon and Vegreville locations. RRTAC has previously funded controlled environment experiments involving charcoal alone, however this project will explore additional amendments. Manure is commonly applied in the field as an amendment, therefore it is being investigated. In addition combinations of charcoal and manure will be examined. Sawdust was chosen because it is a readily available source of organic matter.

Successful amendments and rates determined in the growth chamber studies will be evaluated in the field during the next two growing seasons. In addition field trials will be set up to examine the effect of the number of incorporations conducted on the inactivation of the amendments, and a comparison conducted between fall and spring applications of amendments.

Status: The project is ongoing and is co-funded by the Alberta Environmental Centre.

5.7 PIPELINES

Industry/Government Three-Lift Soil Handling Workshop - D. Hoover, Deloitte & Touche Management Consultants

An industry/government workshop on the three-lift soil handling procedure was held on November 29 and 30, 1990. As outlined in the opening comments by Ian Scott, Canadian Petroleum Association, and John King, Alberta Environment, the workshop provided an opportunity for industry and government to communicate on significant issues relative to the three-lift process.

The workshop included presentations on the first day, and working group discussions on the second day. The main points presented by the working groups are outlined below.

Soil Handling Alternatives. It is generally accepted that three-lift or an alternative to two-lift soil handling procedures is required in some cases. Several soil handling alternatives were identified to resolve concerns addressed by the three-lift procedure. All of the alternatives were thought to have merit, but research may be needed in some cases to assess applicability to specific situations. The main alternatives identified included:

1. Plough-in.
2. Narrow ditch/minimum disturbance.
3. Boring.
4. Two/three-lift for winter.
5. Overstripping.
6. Management over time (cultural, with and without amendments).
7. Incorporation of B/C mix.
8. Landfarming of excess spoil.
9. Amelioration.

Interim Criteria. Both industry and government want clear criteria for materials handling decisions. The general opinion was that the Interim Criteria need to be modified.

Modifiers for the criteria should include considerations such as land use, length of area affected, depth, thickness, soil properties, bedrock texture, geography, and topography. At present, the class boundaries are arbitrary, and no consideration is given to the relative importance of the parameters.

Regarding the lift thickness, it was suggested that there may be a need for a minimum and a maximum thickness for the B horizon, and a specified depth to buffer the A horizon.

Research Proposals. It was indicated that research should be co-funded by industry and government. The goal identified was to determine whether there was a significant difference between two-lift and three-lift in maintaining capability. The following research needs were identified:

1. Any existing information that is applicable should be accessed (i.e., mining data, as-built reports); in addition, a survey of existing pipelines (built since 1980) could be undertaken to gather information such as the effect of time and the relative influence of the parameters.

2. A monitoring program should be set up for new pipelines to gather data on approved and alternate handling procedures. A database of this information should be developed, and would provide a basis for refinement of the guidelines. Monitoring of the lines could be a condition of approval for the lines (on a limited number of lines per year per company). A standard sampling/monitoring procedure would be required to assure comparability of data.

3. A monitoring study of 10 to 12 sites over three to four years, or as required, comparing three-lift sites and pre-disturbance conditions.

4. Additional pure research is needed to address topics such as productivity versus capability, depth to poor quality material, use of amendments, B/C mix ratios, salt movement and time frame, additional disturbance versus three-lift benefits, equipment requirements, etc. Standard sampling and testing methodology would be required to address these needs.

5. After the detailed research is completed, the criteria should be evaluated and revised as necessary.

Status: The project is completed and a final report has been published: RRTAC 90-6.

Reclamation of Mixed Grass Prairie Disturbed by Pipeline Construction - C. Tannas, Eastern Slopes Rangeland Consultants

Alberta's Public Lands Division has serious concerns about the practise of topsoil stripping on rangelands, particularly on the mixed grass prairie. For native grassland under some form of grazing land use, the ultimate concern is to return the disturbed area to a grazable condition. Stripping may also necessitate the use of seeded species that cannot be compatibly grazed with the existing cover. Incompatible species can have the effect of creating strips of primary range problems for the farmer or rancher. Or, in the case of species like crested wheat grass, the seeded line may eventually become non-usable range since crested wheat has a tendency to become rank and unpalatable. In this situation, each pipeline creates an incremental loss to the range forage base although, in theory, the site has been reclaimed. The use of local native plant species is not a proven technology and cannot be relied upon to restore the disturbed area to a compatible cover.

Non-stripped line construction is favoured since the width of disturbance is vastly reduced leaving more native sod intact and even if seeded native species fail to establish, there is a better chance that the native community will encroach from the sod left intact on the trench area.

In summary, stripping has been promoted in the past to conserve topsoil and retain the productive potential of the soil. The concern is that the loss in range productivity from an incompatible cover type on stripped and reseeded range would be greater than the productivity loss due to lost topsoil on the trench area.

The projects objectives are:

1. To demonstrate and compare the major options available to reclaim mixed grass prairie disturbed by pipeline construction.

2. To compare reclamation success: (a) on three separate soils types; (b) with two different methods of soil handling (non-stripped vs blade-width ditch-only); (c) by revegetation with crested wheat grass, an increaser mix, and without seeding; and (d) with and without grazing.

3. To establish demonstration sites for extension activities with industry and other government agencies.

Reclaimed pipeline test plot one year after construction. The fence prevents grazing and allows a comparison with ungrazed areas outside the fence. Note the invasion by prickly pear cactus.

The basic plot design is shown in Figure 8.

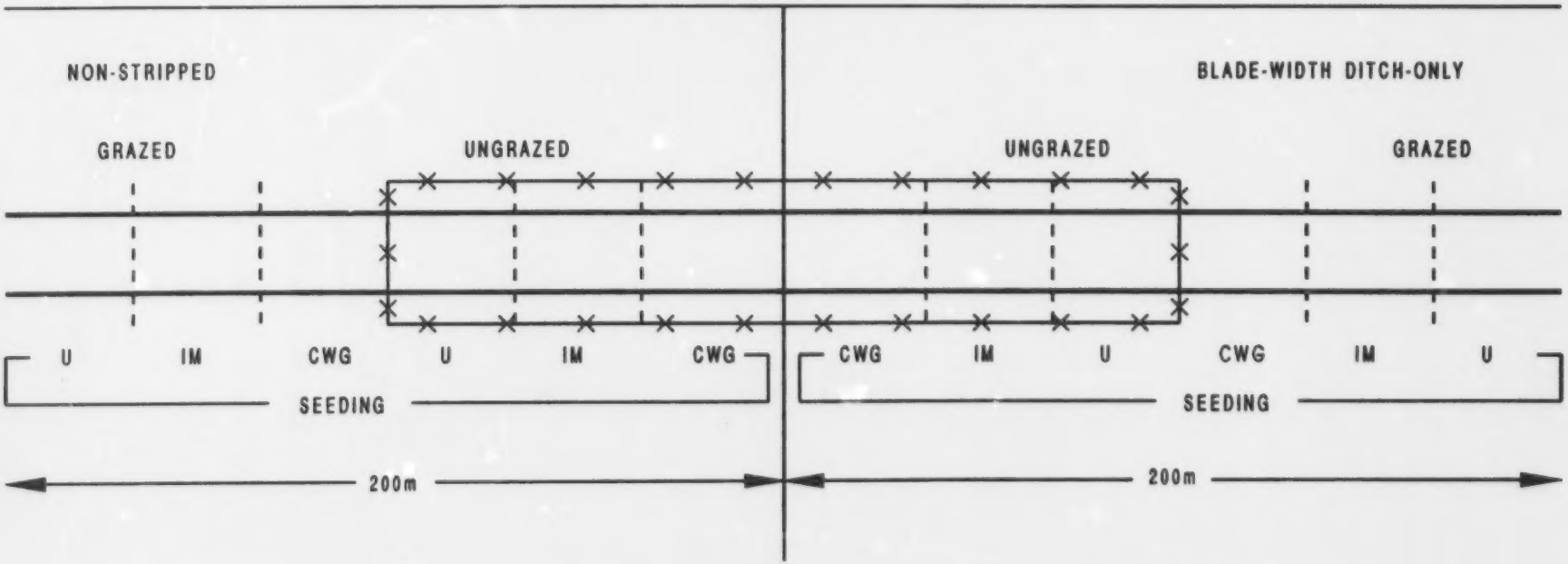
Status: Project is ongoing. Barry Adams, Alberta Forestry, Lands and Wildlife, Public Lands Division in Lethbridge is the project manager for the study. Co-funding for the work has come from LL&E Petroleum and Morrison Petroleum.

Winter Soil Evaluations - A. Twardy, Pedocan Land Evaluation Ltd

A soil evaluation is required in support of a Development and Reclamation Application where arable land or pasture land is disturbed. The evaluation is to provide information about the soils and landforms along a proposed pipeline to assist in soil conservation planning for pipeline construction. Recently there have been some concerns regarding the validity and accuracy of carrying out winter soil evaluations for regulated pipelines. Discussions were held with staff in various government departments and industry, and with consultants who are associated with or affected by winter soil evaluations for regulated pipelines.

The most serious constraint identified in carrying out winter soil evaluations is the ability of the pedologist to distinguish horizons and classify soils properly when there is poor light and when frozen conditions occur in the subsoil. If possible, soil evaluations should be scheduled for summer. If this is not possible, the evaluation can be carried out under less than ideal winter conditions. Some specific soil parameters may be difficult to measure or determine when the soil is frozen and the site inspection and sampling density may have to be increased substantially. Topsoil depth, present land use, and the characteristics and quality of the topsoil and upper and lower subsoils are important parameters that have to be documented in soil evaluations for pipelines. Salt-affected soils are of prime concern. These soils are easily recognized when only the topsoil is frozen but may be difficult to recognize if frost has penetrated deep into the subsoil.

Relative degrees of difficulty in carrying out winter (or summer) soil evaluations in the province have been identified. The depth of



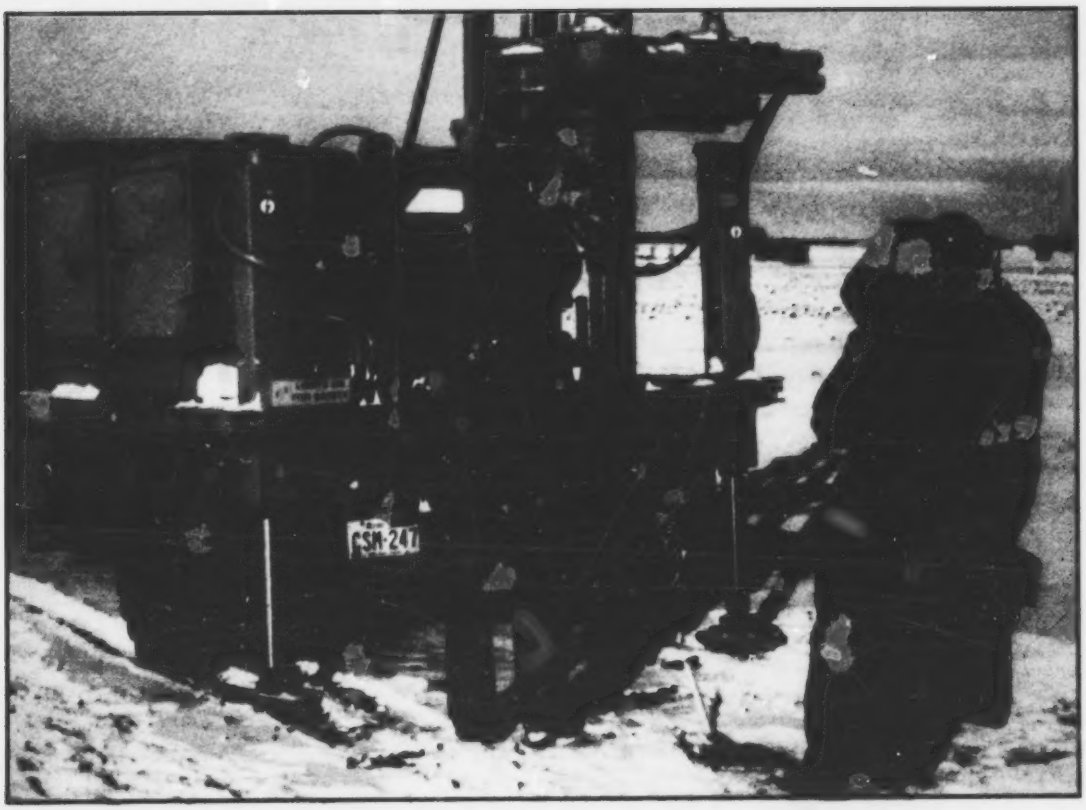
SEEDING TREATMENTS:

U = UNSEEDED
IM = INCREASER MIX
CWG = CRESTED WHEAT GRASS

Figure 8. Plot Layout for the Mixed Grass Prairie Study.

frost, the type of soils that are likely to be encountered, the experience of the pedologist, the amount and type of soils information already available, and the type of equipment that will be used to inspect the soils are factors that have to be considered on a project-by-project basis, prior to initiation of a winter soil evaluation.

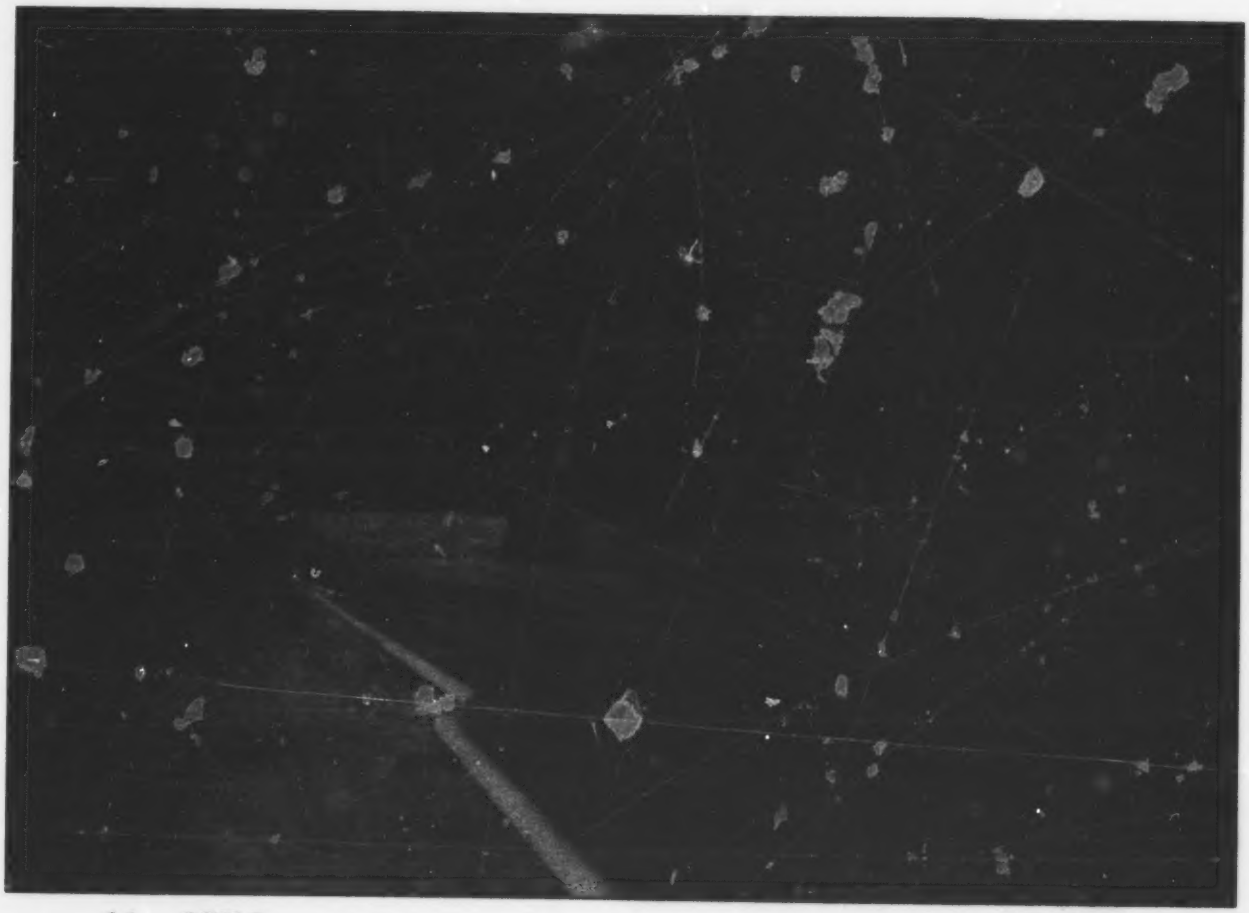
Status: The project is completed and a final report will be available in 1991. The project was co-funded by the Canadian Petroleum Association.



Sampling soils in the winter is not preferred but can provide acceptable information if care is taken in sampling and interpretation of the information.

6. GENERAL PROGRAM

The projects listed under the General Program have application to all the RRTAC Programs and, in some cases, to other disturbance types not studied by RRTAC. These projects are selected and managed by RRTAC rather than by a specific Program Committee.



6.1 SOILS

Review of Physical Properties of Disturbed and Reclaimed Soils - A. Naeth, University of Alberta

To provide coordinated direction for reclamation research in Alberta, the need to review the current understanding and the role of soil physical properties in soil disturbance related activities was identified. Surface coal mining, pipeline and wellhead construction, oil sands extraction, timber harvesting, and agricultural production activities alter the landscape to some degree and their cumulative effect has changed, and will continue to change, the soil resources of the province of Alberta. The nature and severity of these alterations are dependent upon inherent soil properties as affected by disturbance type and the success of reclamation and management practices.

Doll suggested, "the goal of reclamation should be the establishment of a permanently stable landscape, aesthetically and environmentally compatible with the surrounding undisturbed land". Restoration of the productivity of reconstructed soil is a complicated problem. Nielsen et al. stated "In the past, management has been judged on annual measurements of crop productivity, and not on measurements taken below the soil surface that could be used to signal the long term consequences of management of present-day soil and water resources". The emphasis placed on chemical fertility has

often resulted in the neglect of soil physical properties that combine with chemical properties for optimum, sustainable, soil productivity. However, it is often soil physical properties that present the main limitations to reclamation of disturbed lands. The over-emphasis on chemical fertility is attributable, to some extent, to the lack of reliable, quantitative descriptions of soil physical properties in the field. While studying soil physical properties in the laboratory using soil cores and repacked samples has yielded much information on core and repacked samples, there are limited guarantees that such information can be applied to the landscape. In spite of soil physical properties being recognized as one of the critical productivity limiting factors in reclamation, soil chemical properties are still often used as the only criteria of reclamation success because of the difficulty in characterizing soil physical properties.

Often soil scientists, reclamation specialists, and agrologists concerned with management of disturbed lands are forced to seek answers to their questions regarding soil physical properties in a style once described by Oscar Wilde as "Chaos, illumined by flashes of lightning". Measurement of soil physical properties in the field is difficult; subject to spatial and temporal variability, time and length scales, and nonsteady, multidimensional velocity fields in a three phase system. Every soil physical property and process is also modified by weather phenomena (rainfall, frost, solar radiation, and drought), erosion, and human manipulation (management). Often the inability to characterize spatial variability prevents researchers from accurately matching soil use requirements to soil characteristics and, therefore, from predicting soil performance and behaviour. Soil physical properties and processes are closely interconnected, further complicating their measurement. It is also easy to understand why field measurement of soil properties has been described as a "challenge that few have ever accepted" (Nielsen and Biggar). While that challenge is still evident in the measurement of many soil properties, the current challenge is related to selection of those soil physical property measurements that will best answer our questions and the measurement techniques that will best provide that information. We must simplify a complex system by concentrating on the factors which appear to have the greatest and most direct bearing upon the problem at hand.

In the view of White "What properties we need to know and how we measure them are related directly to the questions we are attempting to answer". Through a Soil Physical Properties Workshop held November 1990 for people in Alberta working with soil physical properties and an extensive literature review, the consultant has attempted to identify what questions have been answered, what questions remain unanswered, and what soil physical properties and measurement techniques are best suited to meeting information needs within Alberta. The objective of this review is not to provide a methodology manual or theoretical treatise on soil physics, but rather to assess the various properties and composite parameters and processes in a manner that hopefully will clarify not confound. The report contains a brief overview of field related measurement methodology and spatial and temporal variability for each soil physical property, followed by a review of soil physical property interrelationships, the effects of development/ management activities on these properties, and the prevention/amelioration/ remediation/acceptance strategies employed in dealing with changes in the physical property. Recommendations for future research follow a summary of physical properties most affected by reclamation activities and differences by disturbance type.

Status: The project is completed and a final report will be available in 1991.

A Review of the Land Capability Classification System for use in Reclamation - L. Leskiw, Can-Ag Enterprises Ltd.

The document, Land Capability Classification for Arable Agriculture in Alberta (1987), was developed in response to two interdepartmental concerns:

1. Various government departments were using different systems for rating agricultural lands; and,

2. There was a need for a more specific detailed system to address large scale concerns.

The new system was designed to replace all previous systems in order to provide a single, consistent assessment of agricultural capability in the province.

The goal of reclamation in Alberta is the return of equivalent capability. Over the years, the document has been used by a number of people in disturbed land settings. Some people have identified a need for a review of the criteria in the document, particularly in the evaluation of reclaimed land. Furthermore, there seems to be some misunderstanding about the relationship of this document to the Soil Quality Criteria Relative to Disturbance and Reclamation document, also released in 1987 by Alberta Agriculture.

Thus the Contractor conducted interviews of various system users to determine what changes they would suggest. The interviews also solicited concerns relative to the Soil Quality Criteria document.

The study focused on disturbed and reclaimed land; however, the Contractor also solicited views on the utility of the system for inventorying pre-disturbance land.

The study focused primarily on agricultural land, and the interviews covered all common industrial disturbance types, especially coal mines, well sites and pipelines, where the system has been employed by industry.

The study looked at: the criteria being evaluated; the point deduction method and the values used; timing of evaluation; and the soil depths recommended for evaluation.

Status: The project is completed and a report is in preparation. A second phase of the work may proceed in 1991.

Review of Erosion Control Materials and Methods - D. Walker, David Walker & Associates

Control of erosion on reclaimed sites is critical to the success of any reclamation effort. While a vigorous vegetative growth is generally thought to be the optimum erosion control material, there are specific instances where other materials may be required to successfully control erosion.

The objective of this project is to provide a detailed listing of the options available in Alberta, along with documentation of the use and costs of these options.

Status: The project is completed and a final report is in preparation.

Soil erosion is best reduced by a healthy, vigourous plant cover. However, in some cases it may be necessary to use specialized erosion control measures to ensure soils are stabilized.

Effects of Storage on Topsoil Quality - B. Valleau, Thurber Consultants Limited

Topsoil replacement assists in reclaiming surface disturbances by providing a good seed bed, nutrients, water holding capacity, and a seed source. Topsoil must be removed and replaced on all regulated surface disturbances in Alberta, and usually on non-regulated disturbances. It is generally accepted that immediate replacement enhances the success of the reclamation effort. However, in some operations, such as mountain mines, producing oil and gas wells and batteries, and industrial facilities, topsoil must be stored for several years before it can be used in reclamation.

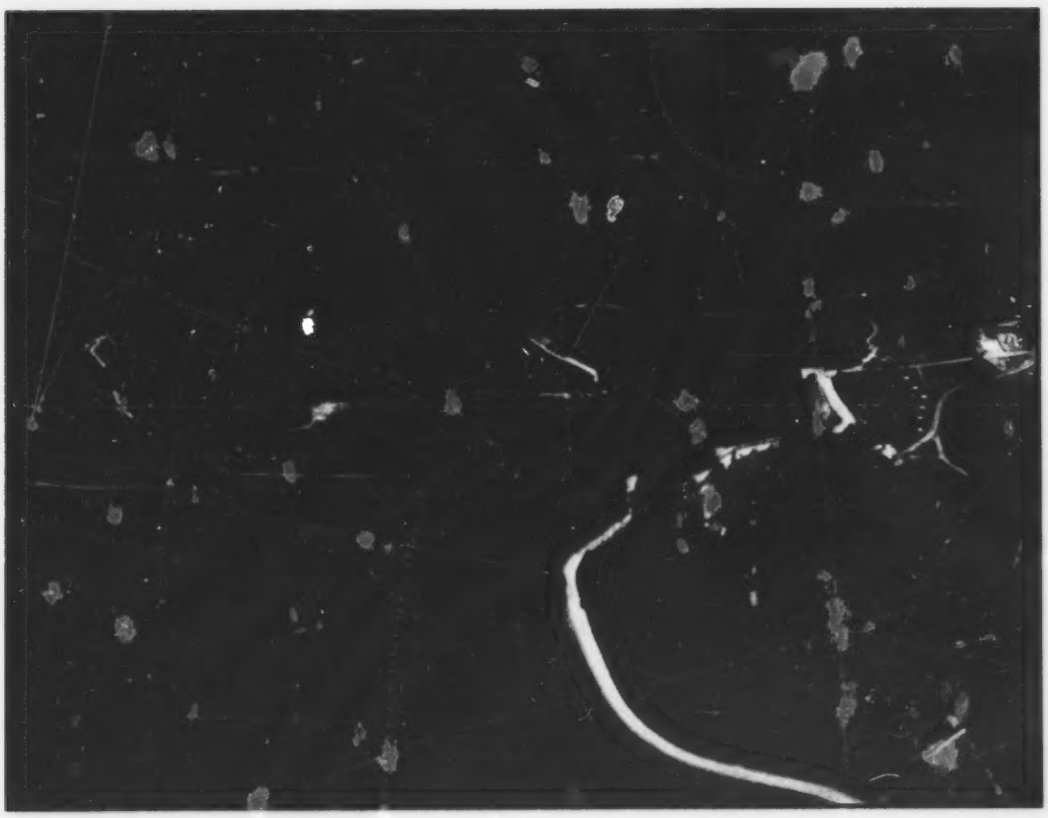
The objective of this project was to review the literature to determine the effects of prolonged topsoil storage on topsoil quality, to determine the best storage methods, and to document the length of time topsoil is stored in various Alberta operations.

Status: The project is completed and a final report has been published: RRTAC 90-5.

A User Guide for Pit and Quarry Reclamation in Alberta - J. Green, The Delta Environmental Management Group

Many pits and quarries in Alberta are reclaimed to exactly the same land use as existed previous to mining. However, there are a number of other reclamation options available to the operator or land owner that may improve the use of the land at little extra cost. This project is designed to develop a manual that will outline the options available for a pit given the surrounding land uses, pit size and depth, presence of water, and other factors. Options discussed include agriculture, forestry, fisheries, wildlife habitat, and residential/ industrial development. The manual will be very graphics-oriented and simply written.

Status: The project is completed and a final report should be available in 1991.



There are several land use options for reclaimed sand and gravel pits.

7. PREVIOUS RESEARCH

7.1 PLAINS COAL RECLAMATION RESEARCH PROGRAM

Objective: Restoration of Agricultural Capability

PROBLEM AREA	RESEARCH PRIORITIES	DESCRIPTION
Groundwater/ Geology	- Effects of mining on groundwater supplies - Generation of salts in spoil - Transport of salts near the reclaimed soil surface - Subsidence after reclamation - Overburden classification	The regions including and surrounding the Battle River and Highvale Mining areas have been intensively monitored to assess the effects of mining on the soil, water and ultimately, the agricultural resources. The hydrology project is completed The long-term effects of subsidence, salinization and soil quality are being monitored by ARC. See RRTAC Reports 80-3, 86-2, 86-3, 86-4, 86-5, 86-6, 86-7, 87-9, 87-10, 87-11, 87-12, 87-13, 88-2, 88-4, 88-9, 88-12, 89-7.
Soil Reconstruction	- Thickness of subsoil required above sodic spoil - Effects of slope on lateral salt transport - Reconstruction of Solonetzic soils - Use of bottom ash as a soil amendment - Effects of crop type - Changes in topsoil during stockpiling	Experimental plots were constructed at the Battle River and Highvale Mine areas and monitored for seven and six crop years, respectively. See RRTAC Reports 88-11, 89-5. An experiment to test optimum amounts of bottom ash and incorporation methods has been completed. See RRTAC Report 87-7.
Fly and Bottom Ash Disposal	- Chemical and physical properties of Alberta fly and bottom ashes - Potential for use as soil amendment	Ashes from five Alberta sources were analyzed for both toxicity and soil amendment possibilities. This work is completed. See RRTAC Report 81-3.

7.2 MOUNTAINS AND FOOTHILLS RECLAMATION RESEARCH PROGRAM

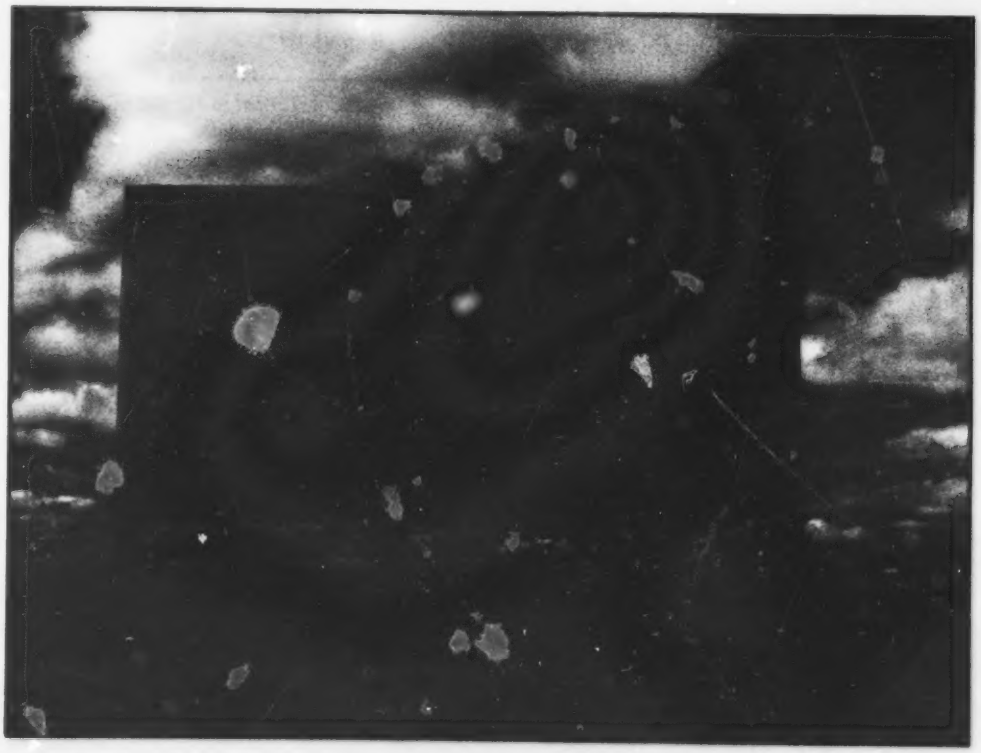
Objective: Restoration of Forestry, Wildlife and Watershed Capabilities

PROBLEM AREA	RESEARCH PRIORITIES	DESCRIPTION
	Design and construction of stable spoil dumps	A survey was conducted of existing reclaimed dumps in Alberta and British Columbia to identify practical resloping strategies. A study of erosion of a variety of dump slopes was conducted. See RRTAC Report 87-8.
Landscape Design	Erosion control	Mulches, binders and contouring techniques for erosion control on coal spoil were evaluated.
	Water management	Settling pond size requirements, the scientific basis for water quality objectives, and methods for predicting sediment production were reviewed and evaluated. See RRTAC Reports 86-2, 87-5, 87-6.
Soil Reconstruction	For various land uses	A literature review and evaluation of soil reconstruction requirements was completed. See RRTAC Report 87-2.
	For reclamation of ash dumps	Thickness of soil required over coal ash to support vegetation was investigated.
Revegetation	Species selection	Development, assessment and field testing of native grasses for reclamation is ongoing.
	Propagation	Methods for propagation of reclamation shrubs were assessed.
	Establishment	Methods for establishment of tree seedlings in grass cover were evaluated.
	Fertilization, nutrients	Studies identified treatments important to development of self-sustaining plant cover. See RRTAC Report 80-1.
	Growth	A method for early prediction of tree growth suitability was developed. See RRTAC Report 88-7.
Wildlife Habitat	Techniques Assessment methods	Literature reviews of methods for wildlife habitat reclamation and measurement of reclamation success were completed. See RRTAC Reports 86-9, 88-1.

7.3 OIL SANDS RECLAMATION RESEARCH PROGRAM

Objective: Restoration of Forestry, Wildlife Capabilities and Erosion Control

PROBLEM AREA	RESEARCH PRIORITIES	DESCRIPTION
Soil Reconstruction on Tailings	Identify recipes for reconstructed soils suitable for: - Commercial forest - Non-commercial forest - Erosion control - Wildlife habitat	Identification of the chemical and microbiological properties of peat, and development of mycorrhizal inoculants for jack pine and other woody species. See RRTAC Reports 84-4, 88-3, 88-5. Identification of soil amendment requirements. See RRTAC Report 83-1. This study was fundamental in designing the oil sand soil reconstruction plots which were constructed in 1983.
Revegetation	- Selection - Propagation - Establishment - Management - Sampling	These projects consisted of literature reviews on tree and shrub selection, seed collection, propagation techniques, and sampling methods for use on the soil reconstruction plots. See RRTAC Reports 83-5, 84-2.



Joint work with industry helps make the RRTAC program more effective.

7.4 OIL AND GAS RECLAMATION RESEARCH PROGRAM

Objective: To develop safe methods of waste disposal and return land to a condition capable of sustaining a designated land use.

PROBLEM AREA	RESEARCH PRIORITIES	DESCRIPTION
Materials Handling	Identify the best methods for handling soil materials in pipeline construction in agricultural land	A survey was made of pipelines of various ages on all of our major agricultural soil types. Material handling methods were assessed and problem areas identified. See RRTAC Report 83-3.
Drilling Muds	Disposal of drilling muds	A literature review of disposal methods for KCl drilling muds was undertaken. See RRTAC Report 87-1.
	Sumps	A review of clay liners for containment of drilling wastes was completed. See RRTAC Report 88-10.
	Siting	A study was completed assessing the feasibility of developing a computer system for evaluating a proposed sump location.
	Characterization	A study of drilling wastes from three regions of the province was completed. See RRTAC Report 89-6.
Sterilants	Amendments	A laboratory study of the effects of activated charcoal for inactivating soil sterilants was completed. See RRTAC Report 89-3.

7.5 GENERAL*

PROBLEM AREA	RESEARCH PRIORITIES	DESCRIPTION
Reclamation Bibliography and Review	Document the findings of reclamation research activities and assess implications for Alberta operations	Worldwide reclamation literature has been reviewed and condensed for presentation in a report which lists and discusses existing information pertinent to reclamation in Alberta. The bibliographic data base is accessible through the University of Alberta computing system. See RRTAC Reports 82-1, 84-1.
Workshops and Conferences	Conduct workshops to determine research needs in Alberta and to disseminate research findings	See RRTAC Reports 80-4 (Forest Soils), 81-3 (Coal Ash), 83-4 (Eastern Slopes Hydrology), 85-1 (Revegetation in Mountains/Foothills), 87-3 (Gel and Saline Drilling Wastes), and 89-2 (Proceedings of the Conference Reclamation, A Global Perspective).
Reference	Provide sources of information for reclamationists	See RRTAC Reports 81-2 (Survey of Activities), 82-2 (Bibliography of Soils, Geology, Hydrology and Groundwater), 88-8 (Alberta Forest Service Watershed Management Field and Laboratory Methods), and 89-4 (Manual of Plant Species Suitability for Reclamation; originally printed RRTAC Report 80-5).

* Projects with province-wide application.

8. 1989/90 RECLAMATION RESEARCH BUDGET

Project No.	Project	1990/91 Budget ($)
PLAINS COAL RECLAMATION RESEARCH PROGRAM		
78-20	CAN-AG Enterprises Ltd. Battle River Soil Reconstruction Project	2 716
89-02	University of Alberta Use of Spoil as Subsoil Material	21 999[1]
90-11	Alberta Research Council Technology Transfer	10 000
MOUNTAINS AND FOOTHILLS RECLAMATION RESEARCH PROGRAM		
90-02	Wild Rose Consulting Inc. Selection of Native Legumes	39 999[3, 9]
OIL SANDS RECLAMATION RESEARCH PROGRAM		
83-07	Hardy BBT Limited Oil Sands Soil Reconstruction Project	25 000
89-10	Hardy BBT Limited Tailings Sand Capping	50 000[2]
90-10	MRRT Limited Evaluation of Sludge Dewatering Techniques	34 724[5]
OIL & GAS RECLAMATION RESEARCH PROGRAM		
89-03	Alberta Research Council Update of the Drilling Waste Disposal Manual	25 000[4]
89-04	Alberta Research Council Landfarming of Diesel Invert Drilling Wastes	75 000[4]
89-12	Alberta Research Council CPA Sump Chemistry Study	48 000[4,6]
90-01	Wild Rose Consulting Inc. Sterilant Issue Scoping	14 999[3]
90-08	Artemis Consulting Development of Reclamation Techniques	22 154[3]
90-07	Deloitte & Touche Three-Lift Soil Handling Workshop	12 000[7,8]
90-03	Eastern Slopes Rangeland Consultants Reclamation of Mixed Grass Prairie	4 640[6]
90-09	Pedocan Land Evaluation Winter Soil Evaluation	12 500[7]
GENERAL PROGRAM		
90-04	University of Alberta Physical Properties of Reclaimed Soils	41 344
90-05	Can-Ag Enterprises Ltd. Review of the Land Capability Classification System	16 000[7]
	Publications	43 537
	TOTAL RRTAC	$ 499 612
	TOTAL OTHERS	$1 028 210

Co-funding Agencies

1 TransAlta Utilities Corporation
2 Syncrude Canada Ltd.
3 Alberta Environmental Centre
4 Alberta Research Council
5 Suncor Inc.
6 Oil and Gas Industry
7 Canadian Petroleum Association
8 Independent Petroleum Association of Canada
9 Canadian Parks Service

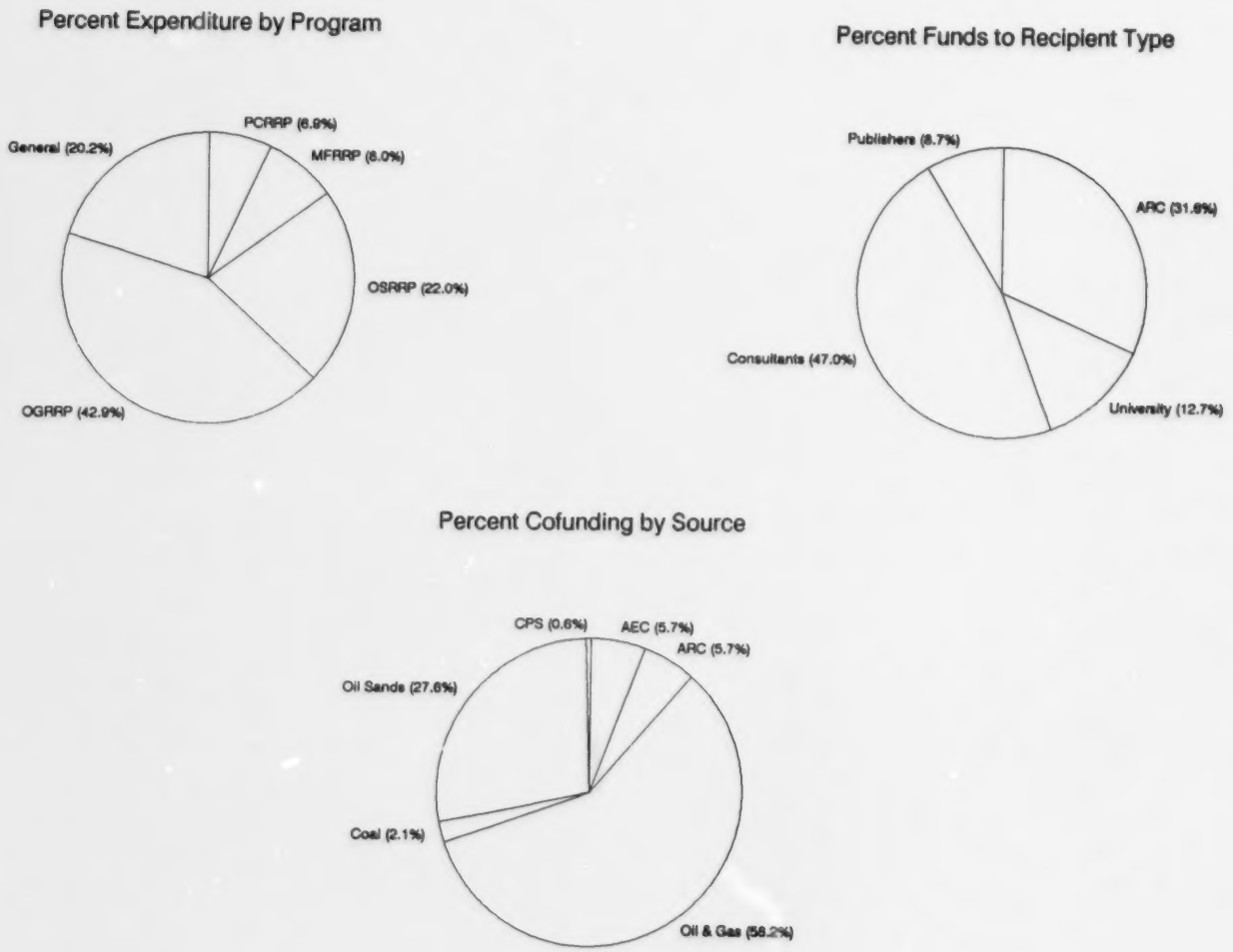


Figure 9. RRTAC Expenditure Information.

9. RECLAMATION RESEARCH REPORTS

RRTAC 79-2: Proceedings: Workshop on Native Shrubs in Reclamation. P.F. Ziemkiewicz, C.A. Dermott and H.P. Sims (Editors). 104 pp. No longer available.

The Workshop was organized as the first step in developing a Native Shrub reclamation research program. The Workshop provided a forum for the exchange of information and experiences on three topics: propagation; outplanting; and, species selection. Seven papers and the results of three discussion groups are presented.

RRTAC 80-1: Test Plot Establishment: Native Grasses for Reclamation. R.S. Sadasivaiah and J. Weijer. 19 pp. No longer available.

The report details the species used at three test plots in Alberta's Eastern Slopes (one at Caw Creek Ridge and two at Cadomin). Site preparation, experimental design, and planting method are also described.

RRTAC 80-3: The Role of Organic Compounds in Salinization of Plains Coal Mining Sites. N.S.C. Cameron et al. 46 pp. No longer available.

This is a literature review of the chemistry of sodic mine spoil and the changes expected to occur in groundwater.

RRTAC 80-4: Proceedings: Workshop on Reconstruction of Forest Soils in Reclamation. P.F. Ziemkiewicz, S.K. Takyi and H.F. Regier (Editors). 160 pp. $10.00

Experts in the field of forestry and forest soils report on research relevant to forest soil reconstruction and discuss the most effective means of restoring forestry capability of mined lands.

RRTAC 80-5: Manual of Plant Species Suitability for Reclamation in Alberta. L.E. Watson, R.W. Parker and D.F. Polster. 2 vols, 541 pp. No longer available; replaced by RRTAC 89-4.

Forty-three grass, fourteen forb, and thirty-four shrub and tree species are assessed in terms of their suitability for use in reclamation. Range maps, growth habit, propagation, tolerance, and availability information are provided.

RRTAC 81-2: 1980 Survey of Reclamation Activities in Alberta. D.G. Walker and R.L. Rothwell. 76 pp. $10.00

This survey is an update of a report prepared in 1976 on reclamation activities in Alberta, and includes research and operational reclamation, locations, personnel, etc.

RRTAC 81-3: Proceedings: Workshop on Coal Ash and Reclamation. P.F. Ziemkiewicz, R. Stein, R. Leitch and G. Lutwick (Editors). 253 pp. $10.00

Presents nine technical papers on the chemical, physical, and engineering properties of Alberta fly and bottom ashes, revegetation of ash disposal sites, and use of ash as a soil amendment. Workshop discussions and summaries are also included.

RRTAC 82-1: Land Surface Reclamation: An International Bibliography. H.P. Sims and C.B. Powter. 2 vols, 292 pp. $10.00

Literature to 1980 pertinent to reclamation in Alberta is listed in Vol. 1 and is also on the University of Alberta computing system (in a SPIRES database called RECLAIM). Vol. 2 comprises the keyword index and computer access manual.

RRTAC 82-2: A Bibliography of Baseline Studies in Alberta: Soils, Geology, Hydrology and Groundwater. C.B. Powter and H.P. Sims. 97 pp. $5.00

This bibliography provides baseline information for persons involved in reclamation research or in the preparation of environmental impact assessments. Materials, up to date as of December 1981, are available in the Alberta Environment Library.

RRTAC 83-1: Soil Reconstruction Design for Reclamation of Oil Sand Tailings. Monenco Consultants Ltd. 185 pp. No longer available

Volumes of peat and clay required to amend oil sand tailings were estimated based on existing literature. Separate soil prescriptions were made for spruce, jack pine, and herbaceous cover types. The estimates form the basis of field trials.

RRTAC 83-3: Evaluation of Pipeline Reclamation Practices on Agricultural Lands in Alberta. Hardy Associates (1978) Ltd. 205 pp. No longer available.

Available information on pipeline reclamation practices was reviewed. A field survey was then conducted to determine the effects of pipe size, age, soil type, construction method, etc. on resulting crop production.

RRTAC 83-4: Proceedings: Effects of Coal Mining on Eastern Slopes Hydrology. P.F. Ziemkiewicz (Editor). 123 pp. $10.00

Technical papers are presented dealing with the impacts of mining on mountain watersheds, their flow characteristics, and resulting water quality. Mitigative measures and priorities were also discussed.

RRTAC 83-5: Woody Plant Establishment and Management for Oil Sands Mine Reclamation. Techman Engineering Ltd. 124 pp. No longer available.

This is a review and analysis of information on planting stock quality, rearing techniques, site preparation, planting, and procedures necessary to ensure survival of trees and shrubs in oil sand reclamation.

RRTAC 84-1: Land Surface Reclamation: A Review of the International Literature. H.P. Sims, C.B. Powter and J.A. Campbell. 2 vols, 1549 pp. $20.00

Nearly all topics of interest to reclamationists including mining methods, soil amendments, revegetation, propagation and toxic materials are reviewed in light of the international literature.

RRTAC 84-2: Propagation Study: Use of Trees and Shrubs for Oil Sand Reclamation. Techman Engineering Ltd. 58 pp. $10.00

This report evaluates and summarizes all available published and unpublished information on large-scale propagation methods for shrubs and trees to be used in oil sand reclamation.

RRTAC 84-3: Reclamation Research Annual Report - 1983. P.F. Ziemkiewicz. 42 pp. $5.00

This report details the Reclamation Research Program indicating priorities, descriptions of each research project, researchers, results, and expenditures.

RRTAC 84-4: Soil Microbiology in Land Reclamation. D. Parkinson, R.M. Danielson, C. Griffiths, S. Visser and J.C. Zak. 2 vols, 676 pp. $10.00

This is a collection of five reports dealing with re-establishment of fungal decomposers and mycorrhizal symbionts in various amended spoil types.

RRTAC 85-1: Proceedings: Revegetation Methods for Alberta's Mountains and Foothills. P.F. Ziemkiewicz (Editor). 416 pp. $10.00

Results of long-term experiments and field experience on species selection, fertilization, reforestation, top-soiling, shrub propagation and establishment are presented.

RRTAC 85-2: Reclamation Research Annual Report - 1984. P.F. Ziemkiewicz. 29 pp. $5.00

This report details the Reclamation Research Program indicating priorities, descriptions of each research project, researchers, results, and expenditures.

RRTAC 86-1: A Critical Analysis of Settling Pond Design and Alternative Technologies. A. Somani. 372 pp. $10.00

The report examines the critical issue of settling pond design, and sizing and alternative technologies. The study was co-funded with The Coal Association of Canada.

RRTAC 86-2: Characterization and Variability of Soil Reconstructed after Surface Mining in Central Alberta. T.M. Macyk. 146 pp. No longer available.

Reconstructed soils representing different materials handling and replacement techniques were characterized, and variability in chemical and physical properties was assessed. The data obtained indicate that reconstructed soil properties are determined largely by parent material characteristics and further tempered by materials handling procedures. Mining tends to create a relatively homogeneous soil landscape in contrast to the mixture of diverse soils found before mining.

RRTAC 86-3: Generalized Procedures for Assessing Post-Mining Groundwater Supply Potential in the Plains of Alberta - Plains Hydrology and Reclamation Project. M.R. Trudell and S.R. Moran. 30 pp. $5.00

In the Plains region of Alberta, the surface mining of coal generally occurs in rural, agricultural areas in which domestic water supply requirements are met almost entirely by groundwater. Consequently, an important aspect of the capability of reclaimed lands to satisfy the needs of a residential component is the post-mining availability of groundwater. This report proposes a sequence of steps or procedures to identify and characterize potential post-mining aquifers.

RRTAC 86-4: Geology of the Battle River Site: Plains Hydrology and Reclamation Project. A. Maslowski-Schutze, R. Li, M. Fenton and S.R. Moran. 86 pp. $10.00

This report summarizes the geological setting of the Battle River study site. It is designed to provide a general understanding of geological conditions adequate to establish a framework for hydrogeological and general reclamation studies. The report is not intended to be a detailed synthesis such as would be required for mine planning purposes.

RTAC 86-5: Chemical and Mineralogical Properties of Overburden: Plains Hydrology and Reclamation Project. A. Maslowski-Schutze. 71 pp. $10.00

This report describes the physical and mineralogical properties of overburden materials in an effort to identify individual beds within the bedrock overburden that might be significantly different in terms of reclamation potential.

RRTAC 86-6: Post-Mining Groundwater Supply at the Battle River Site: Plains Hydrology and Reclamation Project. M.R. Trudell, G.J. Sterenberg and S.R. Moran. 49 pp. $5.00

The report deals with the availability of water supply in or beneath cast overburden to support post-mining land use, including both quantity and quality considerations. The study area is in the Battle River Mining area in east-central Alberta.

RRTAC 86-7: Post-Mining Groundwater Supply at the Highvale Site: Plains Hydrology and Reclamation Project. M.R. Trudell. 25 pp. $5.00

This report evaluates the availability of water supply in or beneath cast overburden to support post-mining land use, including both quantity and quality considerations. The study area is the Highvale mining area in west-central Alberta.

RRTAC 86-8: Reclamation Research Annual Report - 1985. P.F. Ziemkiewicz. 54 pp. $5.00

This report details the Reclamation Research Program indicating priorities, descriptions of each research project, researchers, results, and expenditures.

RRTAC 86-9: Wildlife Habitat Requirements and Reclamation Techniques for the Mountains and Foothills of Alberta. J.E. Green, R.E. Salter and D.G. Walker. 285 pp. No longer available.

This report presents a review of relevant North American literature on wildlife habitats in mountain and foothills biomes, reclamation techniques, potential problems in wildlife habitat reclamation, and potential habitat assessment methodologies. Four biomes (Alpine, Subalpine, Montane, and Boreal Uplands) and 10 key wildlife species (snowshoe hare, beaver, muskrat, elk, moose, caribou, mountain goat, bighorn sheep, spruce grouse, and white-tailed ptarmigan) are discussed. The study was co-funded with The Coal Association of Canada.

RRTAC 87-1: Disposal of Drilling Wastes. L.A. Leskiw, E. Reinl-Dwyer, T.L. Dabrowski, B.J. Rutherford and H. Hamilton. 210 pp. No longer available.

Current drilling waste disposal practices are reviewed and criteria in Alberta guidelines are assessed. The report also identifies research needs and indicates mitigation measures. A manual provides a decision-making flowchart to assist in selecting methods of environmentally safe waste disposal.

RRTAC 87-2: Minesoil and Landscape Reclamation of the Coal Mines in Alberta's Mountains and Foothills. A.W. Fedkenheuer, L.J. Knapik and D.G. Walker. 174 pp. No longer available.

This report reviews current reclamation practices with regard to site and soil reconstruction and re-establishment of biological productivity. It also identifies research needs in the Mountain-Foothills area. The study was co-funded with The Coal Association of Canada.

RRTAC 87-3: Gel and Saline Drilling Wastes in Alberta: Workshop Proceedings. D.A. Lloyd (Compiler). 218 pp. No longer available.

Technical papers were presented which describe: mud systems used and their purpose; industrial constraints; government regulations, procedures and concerns; environmental considerations in waste disposal; and toxic constituents of drilling wastes. Answers to a questionnaire distributed to participants are included in an appendix.

RRTAC 87-4: Reclamation Research Annual Report - 1986. 50 pp. No longer available.

This report details the Reclamation Research Program indicating priorities, descriptions of each research project, researchers, results, and expenditures.

RRTAC 87-5: Review of the Scientific Basis of Water Quality Criteria for the East Slope Foothills of Alberta. Beak Associates Consulting Ltd. 46 pp. $10.00

The report reviews existing Alberta guidelines to assess the quality of water drained from coal mine sites in the East Slope Foothills of Alberta. World literature was reviewed within the context of the East Slopes environment and current mining operations. The ability of coal mine operators to meet the various guidelines is discussed. The study was co-funded with The Coal Association of Canada.

RRTAC 87-6: Assessing Design Flows and Sediment Discharge on the Eastern Slopes. Hydrocon Engineering (Continental) Ltd. and Monenco Consultants Ltd. 97 pp. $10.00

The report provides an evaluation of current methodologies used to determine sediment yields due to rainfall events in well-defined areas. Models are available in Alberta to evaluate water and sediment discharge in a post-mining situation. SEDIMOT II (Sedimentology Disturbed Modelling Techniques) is a single storm model that was developed specifically for the design of sediment control structures in watersheds disturbed by surface mining and is well suited to Alberta conditions. The study was co-funded with The Coal Association of Canada.

RRTAC 87-7: The Use of Bottom Ash as an Amendment to Sodic Spoil. S. Fullerton. 83 pp. No longer available.

The report details the use of bottom ash as an amendment to sodic coal mine spoil. Several rates and methods of application of bottom ash to sodic spoil were tested to determine which was the best at reducing the effects of excess sodium and promoting crop growth. Field trials were set up near the Vesta mine in East Central Alberta using ash readily available from a nearby coal-fired thermal generating station. The research indicated that bottom ash incorporated to a depth of 30 cm using a subsoiler provided the best results.

RRTAC 87-8: Waste Dump Design for Erosion Control. R.G. Chopiuk and S.E. Thornton. 45 pp. $5.00

This report describes a study to evaluate the potential influence of erosion from reclaimed waste dumps on downslope environments such as streams and rivers. Sites were selected from coal mines in Alberta's mountains and foothills, and included resloped dumps of different configurations and ages, and having different vegetation covers. The study concluded that the average annual amount of surface erosion is minimal. As expected, erosion was greatest on slopes which were newly regraded. Slopes with dense grass cover showed no signs of erosion. Generally, the amount of erosion decreased with time, as a result of initial loss of fine particles, the formation of a weathered surface, and increased vegetative cover.

RRTAC 87-9: Hydrogeology and Groundwater Chemistry of the Battle River Mining Area. M.R. Trudell, R.L. Faught and S.R. Moran. 97 pp. No longer available.

This report describes the premining geologic conditions in the Battle River coal mining area including the geology as well as the groundwater flow patterns, and the groundwater quality of a sequence of several water-bearing formations extending from the surface to a depth of about 100 metres.

RRTAC 87-10: Soil Survey of the Plains Hydrology and Reclamation Project - Battle River Project Area. T.M. Macyk and A.H. MacLean. 62 pp. plus 8 maps. $10.00

The report evaluates the capability of post-mining landscapes and assesses the changes in capability as a result of mining, in the Battle River mining area. Detailed soils information is provided in the report for lands adjacent to areas already mined as well as for lands that are destined to be mined. Characterization of the reconstructed soils in the reclaimed areas is also provided. Data were collected from 1979 to 1985. Eight maps supplement the report.

RRTAC 87-11: Geology of the Highvale Study Site: Plains Hydrology and Reclamation Project. A. Maslowski-Schutze. 78 pp. $10.00

The report is one of a series that describes the geology, soils and groundwater conditions at the Highvale Coal Mine study site. The purpose of the study was to establish a summary of site geology to a level of detail necessary to provide a framework for studies of hydrogeology and reclamation.

RRTAC 87-12: Premining Groundwater Conditions at the Highvale Site. M.R. Trudell and R. Faught. 83 pp. $10.00

This report presents a detailed discussion of the premining flow patterns, hydraulic properties, and isotopic and hydrochemical characteristics of five layers within the Paskapoo Geological Formation, the underlying sandstone beds of the Upper Horseshoe Canyon Formation, and the surficial glacial drift.

RRTAC 87-13: An Agricultural Capability Rating System for Reconstructed Soils. T.M. Macyk. 27 pp. $5.00

This report provides the rationale and a system for assessing the agricultural capability of reconstructed soils. Data on the properties of the soils used in this report are provided in RRTAC 86-2.

RRTAC 88-1: A Proposed Evaluation System for Wildlife Habitat Reclamation in the Mountains and Foothills Biomes of Alberta: Proposed Methodology and Assessment Handbook. T.R. Eccles, R.E. Salter and J.E. Green. 101 pp. plus appendix. $10.00

The report focuses on the development of guidelines and procedures for the assessment of reclaimed wildlife habitat in the Mountains and Foothills regions of Alberta. The technical section provides background documentation including a discussion of reclamation planning, a listing of reclamation habitats and associated key wildlife species, conditions required for development, recommended revegetation species, suitable reclamation techniques, a description of the recommended assessment techniques and a glossary of basic terminology. The assessment handbook section contains basic information necessary for evaluating wildlife habitat reclamation, including assessment scoresheets for 15 different reclamation habitats, standard methodologies for measuring habitat variables used as assessment criteria, and minimum requirements for certification. This handbook is intended as a field manual that could potentially be used by site operators and reclamation officers. The study was co-funded with The Coal Association of Canada.

RRTAC 88-2: Plains Hydrology and Reclamation Project: Spoil Groundwater Chemistry and its Impacts on Surface Water. M.R. Trudell (Compiler). 135 pp. $10.00

Two reports comprise this volume. The first "Chemistry of Groundwater in Mine Spoil, Central Alberta," describes the chemical make-up of spoil groundwater at four mines in the Plains of Alberta. It explains the nature and magnitude of changes in groundwater chemistry following mining and reclamation. The second report, "Impacts of Surface Mining on Chemical Quality of Streams in the Battle River Mining Area," describes the chemical quality of water in streams in the Battle River mining area, and the potential impact of groundwater discharge from surface mines on these streams.

RRTAC 88-3: Revegetation of Oil Sands Tailings: Growth Improvement of Silver-berry and Buffalo-berry by Inoculation with Mycorrhizal Fungi and N_2-Fixing Bacteria. S. Visser and R.M. Danielson. 98 pp. $10.00

The report provides results of a study: (1) To determine the mycorrhizal affinities of various actinorrhizal shrubs in the Fort McMurray, Alberta region; (2) To establish a basis for justifying symbiont inoculation of buffalo-berry and silver-berry; (3) To develop a growing regime for the greenhouse production of mycorrhizal, nodulated silver-berry and buffalo-berry; and, (4) To conduct a field trial on reconstructed soil on the Syncrude Canada Limited oil sands site to critically evaluate the growth performance of inoculated silver-berry and buffalo-berry as compared with their un-inoculated counterparts.

RRTAC 88-4: Plains Hydrology and Reclamation Project: Investigation of the Settlement Behaviour of Mine Backfill. D.R. Pauls (compiler). 135 pp. $10.00

This three part volume covers the laboratory assessment of the potential for subsidence in reclaimed landscapes. The first report in this volume, "Simulation of Mine Spoil Subsidence by Consolidation Tests," covers laboratory simulations of the subsidence process particularly as it is influenced by resaturation of mine spoil. The second report, "Water Sensitivity of Smectitic Overburden: Plains Region of Alberta," describes a series of laboratory tests to determine the behaviour of overburden materials when brought into contact with water. The report entitled "Classification System for Transitional Materials: Plains Region of Alberta," describes a lithological classification system developed to address the characteristics of the smectite rich, clayey transition materials that make up the overburden in the Plains of Alberta.

RRTAC 88-5: Ectomycorrhizae of Jack Pine and Green Alder: Assessment of the Need for Inoculation, Development of Inoculation Techniques and Outplanting Trials on Oil Sand Tailings. R.M. Danielson and S. Visser. 177 pp. $10.00

The overall objective of this research was to characterize the mycorrhizal status of Jack Pine and Green Alder which are prime candidates as reclamation species for oil sand tailings and to determine the potential benefits of mycorrhizae on plant performance. This entailed determining the symbiont status of container-grown nursery stock and the quantity and quality of inoculum in reconstructed soils, developing inoculation techniques and finally, performance testing in an actual reclamation setting.

RRTAC 88-6: Reclamation Research Annual Report - 1987. Reclamation Research Technical Advisory Committee. 67 pp. No longer available.

This annual report describes the expenditure of $500,000.00 of Alberta Heritage Savings Trust Fund monies on research under the Land Reclamation Program. The report outlines the objectives and research strategies of the four program areas, and describes the projects funded under each program.

RRTAC 88-7: Baseline Growth Performance Levels and Assessment Procedure for Commercial Tree Species in Alberta's Mountains and Foothills. W.R. Dempster and Associates Ltd. 66 pp. $5.00

Data on juvenile height development of lodgepole pine and white spruce from cut-over or burned sites in the Eastern Slopes of Alberta were used to define reasonable expectations of early growth performance as a basis for evaluating the success of reforestation following coal mining. Equations were developed predicting total seedling height and current annual height increment as a function of age and elevation. Procedures are described for applying the equations, with further adjustments for drainage class and aspect, to develop local growth performance against these expectations. The study was co-funded with The Coal Association of Canada.

RRTAC 88-8: Alberta Forest Service Watershed Management Field and Laboratory Methods. A.M.K. Nip and R.A. Hursey. 4 Sections, various pagings. $10.00

Disturbances such as coal mines in the Eastern Slopes of Alberta have the potential for affecting watershed quality during and following mining. The collection of hydrometric, water quality and hydrometeorologic information is a complex task. A variety of instruments and measurement methods are required to produce a record of hydrologic inputs and outputs for a watershed basin. There is a growing awareness and recognition that standardization of data acquisition methods is required to ensure data comparability, and to allow comparison of data analyses. The purpose of this manual is to assist those involved in the field of data acquisition by outlining methods, practices and instruments which are reliable and recognized by the International Organization for Standardization.

RRTAC 88-9: Computer Analysis of the Factors Influencing Groundwater Flow and Mass Transport in a System Disturbed by Strip Mining. F.W. Schwartz and A.S. Crowe. 78 pp. $10.00

Work presented in this report demonstrates how a groundwater flow model can be used to study a variety of mining-related problems such as declining water levels in areas around the mine as a result of dewatering, and the development of high water tables in spoil once resaturation is complete. This report investigates the role of various hydrogeological parameters that influence the magnitude, timing, and extent of water level changes during and following mining at the regional scale. The modelling approach described here represents a major advance on existing work.

RRTAC 88-10: Review of Literature Related to Clay Liners for Sump Disposal of Drilling Wastes. D.R. Pauls, S.R. Moran and T. Macyk. 61 pp. $5.00

The report reviews and analyses the effectiveness of geological containment of drilling waste in sumps. Of particular importance was the determination of changes in properties of clay materials as a result of contact with highly saline brines containing various organic chemicals.

RRTAC 88-11: Highvale Soil Reconstruction Project: Five Year Summary. D.N. Graveland, T.A. Oddie, A.E. Osborne and L.A. Panek. 104 pp. $10.00

This report provides details of a five year study to determine a suitable thickness of subsoil to replace over minespoil in the Highvale plains coal mine area to ensure return of agricultural capability. The study also examined the effect of slope and aspect on agricultural capability. This study was funded and managed with industry assistance.

RRTAC 88-12: A Review of the International Literature on Mine Spoil Subsidence. J.D. Scott, G. Zinter, D.R. Pauls and M.B. Dusseault. 36 pp. $10.00

The report reviews available engineering literature relative to subsidence of reclaimed mine spoil. The report covers methods for site investigation, field monitoring programs and lab programs, mechanisms of settlement, and remedial measures.

RRTAC 89-1: Reclamation Research Annual Report - 1988. 74 pp. $5.00

This annual report describes the expenditure of $280,000.00 of Alberta Heritage Savings Trust Fund monies on research under the Land Reclamation Program. The report outlines the objectives and research strategies of the four program areas, and describes the projects funded under each program.

RRTAC 89-2: Proceedings of the Conference: Reclamation, A Global Perspective. D.G. Walker, C.B. Powter and M.W. Pole (Compilers). 2 Vols., 854 pp. $10.00

Over 250 delegates from all over the world attended this conference held in Calgary in August, 1989. The proceedings contains over 85 peer-reviewed papers under the following headings: A Global Perspective; Northern and High Altitude Reclamation; Fish & Wildlife and Rangeland Reclamation; Water; Herbaceous Revegetation; Woody Plant Revegetation and Succession; Industrial and Urban Sites; Problems and Solutions; Sodic and Saline Materials; Soils and Overburden; Acid Generating Materials; and, Mine Tailings.

RRTAC 89-3: Efficiency of Activated Charcoal for Inactivation of Bromacil and Tebuthiuron Residues in Soil. M.P. Sharma. 38 pp. $5.00

Bromacil and Tebuthiuron were commonly used soil sterilants on well sites, battery sites and other industrial sites in Alberta where total vegetation control was desired. Activated charcoal was found to be effective in binding the sterilants in greenhouse trials. The influence of factors such as herbicide:charcoal concentration ratio, soil texture, organic matter content, soil moisture, and the time interval between charcoal incorporation and plant establishment were evaluated in the greenhouse.

RRTAC 89-4: Manual of Plant Species Suitability for Reclamation in Alberta - 2nd Edition. Hardy BBT Limited. 436 pp. $10.00

This is an updated version of RRTAC Report 80-5 which describes the characteristics of 43 grass, 14 forb and 34 shrub and tree species which make them suitable for reclamation in Alberta. The report has been updated in several important ways: a line drawing of each species has been added; the range maps for each species have been redrawn based on an ecosystem classification of the province; new information (to 1990) has been added, particularly in the sections on reclamation use; and the material has been reorganized to facilitate information retrieval. Of greatest interest is the performance chart that precedes each species and the combined performance charts for the grass, forb, and shrub/tree groups. These allow the reader to pick out at a glance species that may suit their particular needs. The report was produced with the assistance of a grant from the Recreation, Parks and Wildlife Foundation.

RRTAC 89-5: Battle River Soil Reconstruction Project Five Year Summary. L.A. Leskiw. 188 pp. $10.00

This report summarizes the results of a five year study to investigate methods required to return capability to land surface mined for coal in the Battle River area of central Alberta. Studies were conducted on: the amounts of subsoil required, the potential of gypsum and bottom ash to amend adverse soil properties, and the effects of slope angle and aspect. Forage and cereal crop growth was evaluated, as were changes in soil chemistry, density and moisture holding characteristics.

RRTAC 89-6: Detailed Sampling, Characterization and Greenhouse Pot Trials Relative to Drilling Wastes in Alberta. T.M. Macyk, F.I. Nikiforuk, S.A. Abboud and Z.W. Widtman. 228 pp. $10.00

This report summarizes a three-year study of the chemistry of freshwater gel, Kcl, NaCl, DAP, and invert drilling wastes, both solids and liquids, from three regions in Alberta: Cold Lake, Eastern Slopes, and Peace River/Grande Prairie. A greenhouse study also examined the effects of adding various amounts of waste to soil on grass growth and soil chemistry. Methods for sampling drilling wastes are recommended.

RRTAC 89-7: A User's Guide for the Prediction of Post-Mining Groundwater Chemistry from Overburden Characteristics. M.R. Trudell and D.C. Cheel. 55 pp. $5.00

This report provides the detailed procedure and methodology that is required to produce a prediction of post-mining groundwater chemistry for plains coal mines, based on the soluble salt characteristics of overburden materials. The fundamental component of the prediction procedure is the geochemical model PHREEQE, developed by the U.S. Geological Survey, which is in the public domain and has been adapted for use on personal computers.

RRTAC 90-1: Reclamation Research Annual Report - 1989. 62 pp. $5.00

This annual report describes the expenditure of $480,000.00 of Alberta Heritage Savings Trust Fund monies on research under the Land Reclamation Program. The report outlines the objectives and research strategies of the four program areas, and describes the projects funded under each program.

RRTAC 90-2: Initial Selection for Salt Tolerance in Rocky Mountain Accessions of Slender Wheatgrass and Alpine Bluegrass. R. Hermesh, J. Woosaree, B.A. Darroch, S.N. Acharya and A. Smreciu. 40 pp. $5.00

Selected lines of slender wheatgrass and alpine bluegrass collected from alpine and subalpine regions of Alberta as part of another native grass project were evaluated for their ability to emerge in a saline medium. Eleven slender wheatgrass and 72 alpine bluegrass lines had a higher percentage emergence than the Orbit Tall Wheatgrass control (a commonly available commercial grass). This means that as well as an ability to grow in high elevation areas, these lines may also be suitable for use in areas where saline soil conditions are present. Thus, their usefulness for reclamation has expanded.

RRTAC 90-3: Natural Plant Invasion into Reclaimed Oil Sands Mine Sites. Hardy BBT Limited. 65 pp. $5.00

Vegetation data from reclaimed sites on the Syncrude and Suncor oil sands mines have been summarized and related to site and factors and reclamation methods. Natural invasion into sites seeded to agronomic grasses and legumes was minimal even after 15 years. Invasion was slightly greater in sites seeded to native species, but was greatest on sites that were not seeded. Invasion was mostly from agronomic species and native forbs; native shrub and tree invasion was minimal.

RRTAC 90-4: Physical and Hydrological Characteristics of Ponds in Reclaimed Upland Landscape Settings and their Impact on Agricultural Capability. S.R. Moran, T.M. Macyk, M.R. Trudell and M.E. Pigot, Alberta Research Council. 76 pp. $5.00

The report details the results and conclusions from studying a pond in a reclaimed upland site in Vesta Mine. The pond formed as a result of two factors: (1) a berm which channelled meltwater into a series of subsidence depressions, forming a closed basin; and (2) low hydraulic conductivity in the lower subsoil and upper spoil as a result of compaction during placement and grading which did not allow for rapid drainage of ponded water. Ponds such as this in the reclaimed landscape can affect agricultural capability by: (1) reducing the amount of farmable land (however, the area covered by these ponds in this region is less than half of that found in unmined areas); and, (2) creating the conditions necessary for the progressive development of saline and potentially sodic soils in the area adjacent to the pond.

RRTAC 90-5: Review of the Effects of Storage on Topsoil Quality. Thurber Consultants Ltd., Land Resources Network Ltd., and Norwest Soil Research Ltd. 116 pp. $10.00

The international literature was reviewed to determine the potential effects of storage on topsoil quality. Conclusions from the review indicated that storage does not appear to have any severe and longterm effects on topsoil quality. Chemical changes may be rectified with the use of fertilizers or manure. Physical changes appear to be potentially less serious than changes in soil quality associated with the stripping and respreading operations. Soil biotic populations appear to revert to pre-disturbance levels of activity within acceptable timeframes. Broad, shallow storage piles that are seeded to acceptable grass and legume species are recommended; agrochemical use should be carefully controlled to ensure soil biota are not destroyed.

RRTAC 90-6: Proceedings of the Industry/Government Three-Lift Soils Handling Workshop. Deloitte & Touche. 168 pp. $10.00

This report documents the results of a two-day workshop on the issue of three-lift soils handling for pipelines. The workshop was organized and funded by RRTAC, the Canadian Petroleum Association and the Independent Petroleum Association of Canada. Day one focused on presentation of government and industry views on the criteria for three-lift, the rationale and field data in support of three- and two-lift procedures, and an examination of the various soil handling methods in use. During day two, five working groups discussed four issues: alternatives to three-lift; interim criteria and suggested revisions; research needs; definitions of terms. The results of the workshop are being used by a government/industry committee to revise soils handling criteria for pipelines.

RRTAC 90-7: Reclamation of Disturbed Alpine Lands: A Literature Review. Hardy BBT Limited. 209 pp. $10.00

This review covers current information from North American sources on measures needed to reclaim alpine disturbances. The review provides information on pertinent Acts and regulations with respect to development and environmental protection of alpine areas. It also discusses: alpine environmental conditions; current disturbances to alpine areas; reclamation planning; site and surface preparation; revegetation; and, fertilization. The report also provides a list of research and information needs for alpine reclamation in Alberta.

RRTAC 90-8: Plains Hydrology and Reclamation Project: Summary Report. S.R. Moran, M.R. Trudell, T.M. Macyk and D.B. Cheel. 105 pp. $10.00

This report summarizes a 10-year study on the interactions of groundwater, soils and geology as they affect successful reclamation of surface coal mines in the plains of Alberta. The report covers: Characterization of the Battle River and Wabamun study areas; Properties of reclaimed materials and landscapes; Impacts of mining and reclamation on post-mining land use; and, Implications for reclamation practice and regulation. This project has led to the publication of 18 RRTAC reports and 22 papers in conference proceedings and refereed journals.

RRTAC 90-9: Literature Review on the Disposal of Drilling Waste Solids. Monenco Consultants Limited. 83 pp. $5.00

This report reviews the literature on, and government and industry experience with, burial of drilling waste solids in an Alberta context. The review covers current regulations in Alberta, other provinces, various states in the US and other countries. Definitions of various types of burial are provided, as well as brief summaries of other possible disposal methods. Environmental concerns with the various options are presented as well as limited information on costs and monitoring of burial sites. The main conclusion of the work is that burial is still a viable option for some waste types but that each site and waste type must be evaluated on its own merits.

RRTAC 90-10: Potential Contamination of Shallow Aquifers by Surface Mining of Coal. M.R. Trudell, S.R. Moran and T.M. Macyk. 75 pp. $5.00

This report presents the results of a field investigation of the movement of salinized groundwater from a mined and reclaimed coal mine near Forestburg into an adjacent unmined area. The movement is considered to be an unusual occurrence resulting from a combination of a hydraulic head that is higher in the mined area than in the adjacent coal aquifer, and the presence of a thin surficial sand aquifer adjacent to the mine. The high hydraulic head results from deep ponds in the reclaimed landscape that recharge the base of the spoil.